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EFFECT OF AIRPLANE DESIGN EFFICIENCY AND ENGINE ECONOMY ON RANGE

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NACA

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MEMORANDUM REPORT

for

Army Air Forces, Materiel Command

EFFECT OF AIRPLANE DESIGN EFFICIENCY AND ENGINE ECONOMY ON RANGE

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SUMMARY

The parameters affecting performance of an airplane are divided into two groups, (1) primary parameters (altitude, power, gross weight, and wing area) and (2) secondary or "efficiency" parameters (engine economy, aerodynamic efficiency, and structural efficiency). This report examines the effect of magnified variations of the efficiency parameters to determine their influence upon performance.

The analysis shows that the efficiency parameters when compared to the primary parameters are extremely ineffective in adjusting the airplane performance to its tactical mission. The values of the efficiency parameters are constantly being improved by development and research, and therefore the absolute performance values are gradually increasing with time. It is shown, however, that improvement in these parameters is no substitute for the proper choice of the primary parameters.

The appendix shows that changes in the values of the efficiency parameters in the calculation of the usual performance selection charts have very little effect upon the broad trends in performance as affected by wing and power loading.

The analysis shows that for a typical case the ultimate range of an airplane may be increased approximately 1 percent by a 1-percent reduction in specific fuel consumption, or a 2-percent reduction in profile drag, or a 1-percent reduction in the structural weights.

The primary parameters may be selected to give wide variations of performance regardless of the efficiency parameter. On the other hand no choice of efficiency parameters is permissible. Efficiency parameters are subject to continued evolution and at any given date the best values will be used.

INTRODUCTION

The NACA in cooperation with the military services has made a study in which airplane performance has been graphically related to airplane parameters. These parameters are divided into two groups.

Primary (dimensional)	Secondary (efficiency)
Altitude	Engine economy
Power	Aerodynamic efficiency
Gross weight	Structural efficiency
Wing area	

The reports (references 1, 2, 3, and 4) have been concerned with relating the performance and primary parameters while the secondary parameters were held constant.

This report examines the effect of magnified variations of the secondary or efficiency parameters to determine their influence upon the performance. The effect of efficiency parameters on performance is computed for two bombers, that is, for two sets of primary parameters.

A true perspective of the relation between primary and efficiency parameters is of great assistance in the specification and design of an airplane and presents a clear conception of the responsibility placed upon tactical, procurement, industrial, and research personnel.

To all practicable purposes the primary parameters are determined by the type of the airplane and the requirements of the mission and are therefore indirectly defined by the tactician. It is very important that this fact be realized because, once the requirements of the mission are set, very little choice remains to the procurement, industrial, or research personnel. Therefore the tactician must have a means of rapidly relating the performance of the airplane to its dimensional parameters in order to appreciate the compromise that is made.

Once the type and mission of the airplane are fixed, the differences between airplanes are determined by changes in the secondary or efficiency parameters. The entire efforts of research and development are directed towards the gradual improvement of these efficiency parameters.

An appendix presents the usual performance selection charts with values of the efficiency parameters used in this report.

ANALYSIS

General

Two representative bombers have been selected to relate changes of the subject parameters to range and bomb capacity. These are powered by four 2000-horsepower engines supercharged to 35,000 feet altitude. One is a fast bomber with a wing loading of 70 pounds per square foot and a power loading of 12 pounds per horsepower, that is, a wing area of 1370 square feet and a gross weight of 96,000 pounds. The second bomber is designed with the same take-off distance as the first but has greater cargo capacity and range capabilities. The second bomber has a wing loading of 40 pounds per square foot and a power loading of 25 pounds per horsepower, which means a wing area of 5000 square feet and a gross weight of 200,000 pounds. These bombers have the performances shown by their location on the selection chart (fig. 1).

The effect of the efficiency parameters on range is demonstrated by means of range-bomb load curves, giving range comparisons for all values of bomb load. Unless otherwise stated, all range values are those obtainable at the maximum L/D condition.

Specific Fuel Consumption

The variations of specific fuel consumption as a function of engine power for this study are given in figure 2. The "production" curve represents a good installation of a

production engine in an airplane. This is taken as the basic curve of specific fuel consumption for the remainder of the studies. The "better-cooling" curve represents what might be obtained if better cooling of the engine were provided or better fuels permitted higher power with lean mixtures. The "test-stand" curve represents the best probable for a conventional four-stroke-cycle gasoline aviation engine under ideal test-stand operating conditions. The "ideal" curve represents what might be obtained if no limitations on engine operation existed and an efficient engine cycle using high compression ratio were used. The "nonoptimum installation" curve represents what might be obtained for an installation that suffers from defects that prohibit operation at minimum specific fuel consumption. Examples of such defects are (1) insufficient cooling in either the engine, intercooler, or oil cooler, (2) an undersized propeller that does not permit operation at minimum specific fuel consumption without stalling of the propeller blades, (3) poor supercharging, (4) large duct losses, (5) poor distribution of fuel, and many other defects too numerous to mention.

The effect of the above variations in specific fuel consumption on the range-bomb load curves is shown in figures 3, 4, 5, and 6. In the calculations for these curves it is assumed that the bomb load is dropped at half

the range. Two methods of flying these airplanes are presented in the figures, (1) the sea-level maximum L/D condition and (2) the condition of rated power and maximum altitude up to the critical altitude that can be flown at rated power and maximum L/D.

The sea-level maximum L/D condition of flight, shown in figures 3 and 4, represents the greatest range capabilities of these airplanes. It may be noted in figure 3 that a change from the production curve to the better cooling curve of figure 2 makes no change in range. This means that the range operation of this 96,000-pound airplane is at a specific fuel consumption of 0.425 pound per horsepower-hour and therefore no change could be expected. The 200,000-pound airplane of figure 4 shows some improvement in range with the better cooling engine.

The curves for the maximum continuous rated power condition, figures 5 and 6, show much greater differences in range for the changes in specific fuel consumption. These curves are computed for 1675 horsepower per engine for the entire flight. Climb is made at maximum L/D to 35,000 feet, after which operation continues at 35,000 feet.

Flight under these conditions represents the approximate minimum time condition and it is interesting to note how here again "haste makes waste." Comparing figures 3 and 5 it may be seen that it requires the ideal engine to fly as far for

this high-speed condition as the production engine can fly under ideal operating conditions. The largest advantage in the improvement of the specific fuel consumption is demonstrated when military conditions demand a high-speed mission.

Aerodynamic Refinement

The variation in aerodynamic refinement corresponds to a total change in profile drag of two to one. The values corresponding to "production" line airplanes have a wing profile drag coefficient of 0.0090, a tail drag coefficient based on wing area of 0.0030 and a body drag coefficient of 0.12 based on the effective body frontal area. The "model" drag coefficient corresponds to what may be demonstrated in a wind-tunnel test providing that all large interference drags have been eliminated by proper alinement of the bodies and wings and the air flow is allowed sufficient length to expand without breakdown of flow. The futuristic drag coefficient is a drag coefficient that may be obtained some time in the future.

The effect of these changes in aerodynamic refinement on the range and bomb capacity for the sea-level maximum L/D condition is given in figures 7 and 8. These figures look very similar to those of figures 3 and 4 where specific fuel consumption was varied. A comparison of the

futuristic curve of figure 7 with the production curve of figure 8 shows that the selection of the proper power loading for maximum range is as effective in obtaining range as the halving of the profile drag coefficient.

Structural Weight

The normal structural weight is given as that required for a production wing with a design load factor of 4 with a 6770-pound bomb load in the fuselage and the fuel load distributed along the wing, a root wing thickness of 20 percent, and an aspect ratio of 12. The 70-percent structural weight represents what might be obtained with lower load factors, better construction, more perfectly distributed loads, and perhaps greater wing thickness providing the drag of the wing did not increase appreciably. The structural weight of 1.30 times normal represents what may be expected with either poorer construction, greater load factors, thinner wings, or large concentrated loads in the fuselage.

The effect of these variations in structural weight is given in figures 9 and 10. The effect is nearly uniform for any range of operation and differs in this manner from the other two parameters investigated. The relative importance of structural weight for the larger airplane is readily apparent from the spacing of the curves.

If it is desired to use an airplane to bomb a target that requires it to operate near its ultimate range, the

importance of structural weight could not be overemphasized. For example, in figure 10, if the airplane is required to bomb a target 4000 miles from the base, it is seen that an airplane with normal structural weight can carry 10,000 pounds of bombs while, if the structural weight were reduced to 70 percent, it could carry 34,000 pounds of bombs. This means that, for a given weight of bombs, less than one-third of the airplanes is required for such a mission.

Fixed Weights

While the above examples were worked for a given structural weight variation, the example may be applied with sufficient accuracy to any weight item by the use of the bomb-load ordinate. If 10,000 pounds are saved on equipment or crew, the corresponding range may be estimated by drawing a curve adjusted for this weight increment between the structural weight curves of figures 9 or 10.

Combination of the Effects

The effect of combining the variation of the parameters in a single design is shown in figures 11 and 12. These figures show that an airplane with a 20,000-mile range is extremely hard to obtain. The significance of this fact becomes more apparent when it is realized that the 200,000-pound bomber used in this study was selected because it was nearly optimum for range from the studies of references 1 to 4.

A good approximation to the long range curves in figures 11 and 12 may be obtained by using the product of the range ratios for the separate effects to obtain the range end of the curve and the sum of the weight effects for the bomb-load end of the curve.

For example, for figure 11

$$\text{Range} = \underset{\substack{\text{From}\\\text{figure 4}}}{\left(\frac{11,150}{9,060}\right)} \underset{\substack{\text{From}\\\text{figure 8}}}{\left(\frac{10,950}{9,060}\right)} \underset{\substack{\text{From}\\\text{figure 10}}}{\left(\frac{11,750}{9,060}\right)} (9,060) = 17,450 \text{ miles}$$

The other end point is read directly from figure 10 and the curve may be constructed by noticing the shape of the curves in all the figures. This method may be used for evaluation of airplanes with particular design features.

DISCUSSION

An examination of the figures showing the increase in range with improvements in engine, aerodynamic, and structural efficiency shows clearly that at any given date the practicable improvement in range is a matter of a few hundred miles if the dimensional parameters are held constant. There is a small margin in possible performance between the best and the poorest airplanes of any given design date.

These differences apply with almost equal effect regardless of where the airplane falls on the selection charts.

The most marked changes come when the primary parameters are changed and airplanes are selected at various points on the charts.

A very confusing situation can be set up when some of the primary factors are varied at the same time that an efficiency parameter is varied. If the change in performance is attributed to the efficiency parameter, then a completely erroneous estimate of cause and effect is obtained. There are few cases where one thing at a time is changed in an airplane so that the relation between the change and the performance is uniquely determined.

For instance, if it is desired to determine the effect of the wing section on airplane performance, the wing area, plan form, thickness, and lift distribution must be maintained constant in the process.

Or, when the effect of a new design of engine cowling is to be determined, the cooling equipment, engine power, critical altitude, etc., must remain unchanged if a true evaluation of the change is to be obtained.

In other words, if a true evaluation of any change on an airplane is to be obtained, it is an elementary fact that <u>only</u> that change in the airplane may be made. Since such a change is rarely, if ever, made to an airplane, it is important that the conclusions drawn include all of the changes and that these effects are not related to only the visual changes in external appearance.

Each new design of airplane, engine, wing section, cowling, propeller, or innumerable other details appears to introduce a revolution in airplane performance. When the airplanes of the past and present are examined, many novel features are observed but the striking feature of all is that their performances are, with appropriate allowance for date of design and type such as pursuit, bomber, etc., more nearly defined by their weight, wing area, power, and altitude of operation rather than by the differences in the efficiency of the design. The designer invariably believes that he has the secret to the superdesign but by the time the model of the airplane has been tested, the engine cooling assured, the requirements dictated by the mission for which the airplane is designed, and a host of other circumstances, airplanes, in general, turn out to be equal in so far as their altitude of operation, wing loading, and power loading will allow. There is simply an over-all gradual improvement of airplanes. The startling improvements and high hopes add up in the finished airplanes to make a gradual evolution of the airplane which may be observed as time goes on.

CONCLUDING REMARKS

An analysis has been presented which shows the variation in performance of two bombers with variations in engine, aerodynamic, and structural efficiency. The analysis shows that these efficiency parameters are comparatively ineffective in changing performance.

The dimensional parameters (gross weight, power, wing area, and altitude) are determined by the requirements of the mission and the type of the airplane and are therefore fixed by the airplane specification.

The efficiency parameters (engine, aerodynamic, and structural efficiency) apply with equal force to all airplanes regardless of the primary parameters. The efficiency parameters undergo a continuous evolution with time. The efforts of research and development are entirely directed toward the improvement of these parameters.

Improvement of efficiency parameters is no substitute for the proper choice of the primary parameters. In evaluating the effect of parameters, it is absolutely essential that the influence of the two types of parameters be segregated.

The analysis shows that the ultimate range of an airplane may be increased approximately 1 percent by a 1-percent reduction in specific fuel consumption, or a 2-percent reduction in profile drag, or a 1-percent reduction in the structural weights for a typical case.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 1, 1942.

APPENDIX

The NACA has been making a study of the effect of airplane parameters on airplane performance (references 1 to 3). In these studies the major airplane parameters are taken as altitude, power, gross weight, and wing area, and the effect of these on airplane performances is given in the form of selection charts. In order to show these broad effects, it was necessary to fix some systematic variation of such parameters as specific fuel consumption, fixed and structural weights, and aerodynamic refinement. These parameters were varied in a manner that corresponded as nearly as possible to present-day production airplanes. Research and development on the improvement of these parameters lead to an ever-changing picture. It is the purpose of this appendix to show the effect of wide variations in these parameters on the values and trends of the selection charts.

Basic Condition

The selection charts for the basic condition are given in figure 13. The maximum range with no bomb load is given in figure 13(a). The range is calculated with a propeller efficiency of 80 percent, a specific fuel consumption corresponding to the production curve of figure 2, and a power equal to that required to fly at maximum L/D at sea level. A span-load efficiency factor of 0.8 was

used in the calculations. For combat operating conditions this range must be multiplied by a factor of safety to take care of adverse weather conditions and high-speed operation over the target. The ultimate range without these allowances is used for the comparisons in the paper since a value for this factor is beyond the scope of this paper.

The disposable load which includes gasoline, oil, and bombs, but excludes military equipment and crew, is given in figure 13(b). Of this disposable load it has been assumed in this report that 6700 pounds are bombs carried in the fuselage and the remainder is a distributed load along the wing span. If more bombs or cargo are carried in the fuselage, the design load factor of 4 will not be maintained.

The speed, rate of climb, and take-off performances are given in figure 13(c). The speed is calculated using 2000 horsepower at 35,000 feet altitude with an effective propeller efficiency of 75 percent. It is here assured that the propulsive efficiency is lowered to 75 percent by the cooling requirements for this altitude. The drag coefficient of the airplane is taken as

$$C_{D_o} = 0.0120 + 0.12\ F/S$$

where F is the effective frontal area of the bodies and S is the wing area.

The rate of climb is calculated for maximum L/D, full load, and at sea level with 2000 horsepower. The effective propeller efficiency is assumed to be 80 percent.

The take-off distance is the ground run calculated for sea level, hard runway, and a take-off $C_L = 1.3$.

Figure 13(d) gives the structural weight and gas, oil, and bombs as a percentage of the gross weight.

Figure 13(e) shows the variation of maximum L/D with gross weight and wing area for the basic condition.

Specific Fuel Consumption

The variation in specific fuel consumption shown in figure 2 affects the selection charts only with respect to ultimate range. The range charts for the better-cooling curve of figure 2 are given in figure 14, for the test-stand curve in figure 15, for the ideal curve in figure 16, and for the nonoptimum curve in figure 17.

A comparison of the above figures and those of figure 13(a) shows that the greatest effect of specific fuel consumption on the trends of the charts is in the curvature of the constant range curves at the high wing and power loadings. This shows that the major reason for the existence of a sharp optimum wing loading for range at high power loading is the increase in specific fuel consumption as the engine output approaches full power.

The trends in range as effected by the power loading at medium wing loadings are very little changed by the specific fuel consumption of the engine.

Aerodynamic Refinement

The aerodynamic refinement of the airplane affects all of the performance characteristics except the maximum disposable load which is given in figure 13(b). The selection charts for airplanes with a drag coefficient based on wind-tunnel model tests are given in figure 18 and for the futuristic design in figure 19.

A careful comparison of the trends of performance in figures 13, 18, and 19 shows no major effect of aerodynamic refinement. The speed, range, and rate of climb are all increased by the lower drag which would affect the selection of an airplane for a given mission, but the general trends with wing loading and power loading remain unchanged.

Structural Weight

The percentage of airplane weight required for structural weight affects the range, disposable load, and weight charts, but leaves the other selection charts unchanged. Figure 20 shows the revised charts for 70 percent of the normal structural weight and figure 21 the charts for 130 percent of the normal structural weight.

The main effect of structural weight is to change the optimum power loading for maximum range. The low structural weight increases the optimum power loading and the high structural weight reduces it.

Fixed Weights

Changing the fixed weights affects the values of range, disposable load, and weight charts. Fixed weights as defined here include armor, armament, crew, and equipment, electrical and hydraulic equipment, communications, instruments, and cabin supercharging, but not power plants. Figure 22 shows the charts for 70 percent of the fixed weights and figure 23 for 130 percent of the fixed weights.

Variation in the fixed weights seems to have very little effect on the trends of the charts and only affects the values.

Combining the Changes in Specific Fuel Consumption, Aerodynamic Refinement, and Structural Weight

The combination of these effects presents only a single new selection chart on range, figure 24. The speed, rate of climb, and take-off distance are shown in figure 18(b), the disposable load in figure 20(b), the weight chart in figure 20(c), and the L/D chart in figure 18(c).

The combination of these effects shows large range values and curves of constant range that are nearly independent of wing loading. It may be noted that the optimum

power loading for range is above a power loading of 30 pounds per horsepower for these optimistic conditions.

General Discussion

The presentation of trends in airplane performance characteristics as a function of only wing and power loading at first may seem too simple a conception to be of use to designers. So many factors affect the absolute values of the performances that the trends might also be basically affected. The purpose of this appendix was to show how the values on the charts may be radically affected while the broad trends in performance remain basically the same. These broad trends may be summarized as follows:

1. Maximum range and cargo capacity are primarily dependent on power loading and only slightly dependent on wing loading.

2. Speed is dependent on both the wing and power loading. If an airplane with low wing and power loading is overloaded, the speed is only slightly affected. (This condition may be shown by a straight line drawn through the origin and the point representing the wing and power loading of the airplane.)

3. Rate of climb is primarily affected by the power loading and only slightly dependent on the wing loading.

4. Take-off distance is dependent upon both wing and power loading but need not be made long in order to get great range providing the proper choice of parameters is made.

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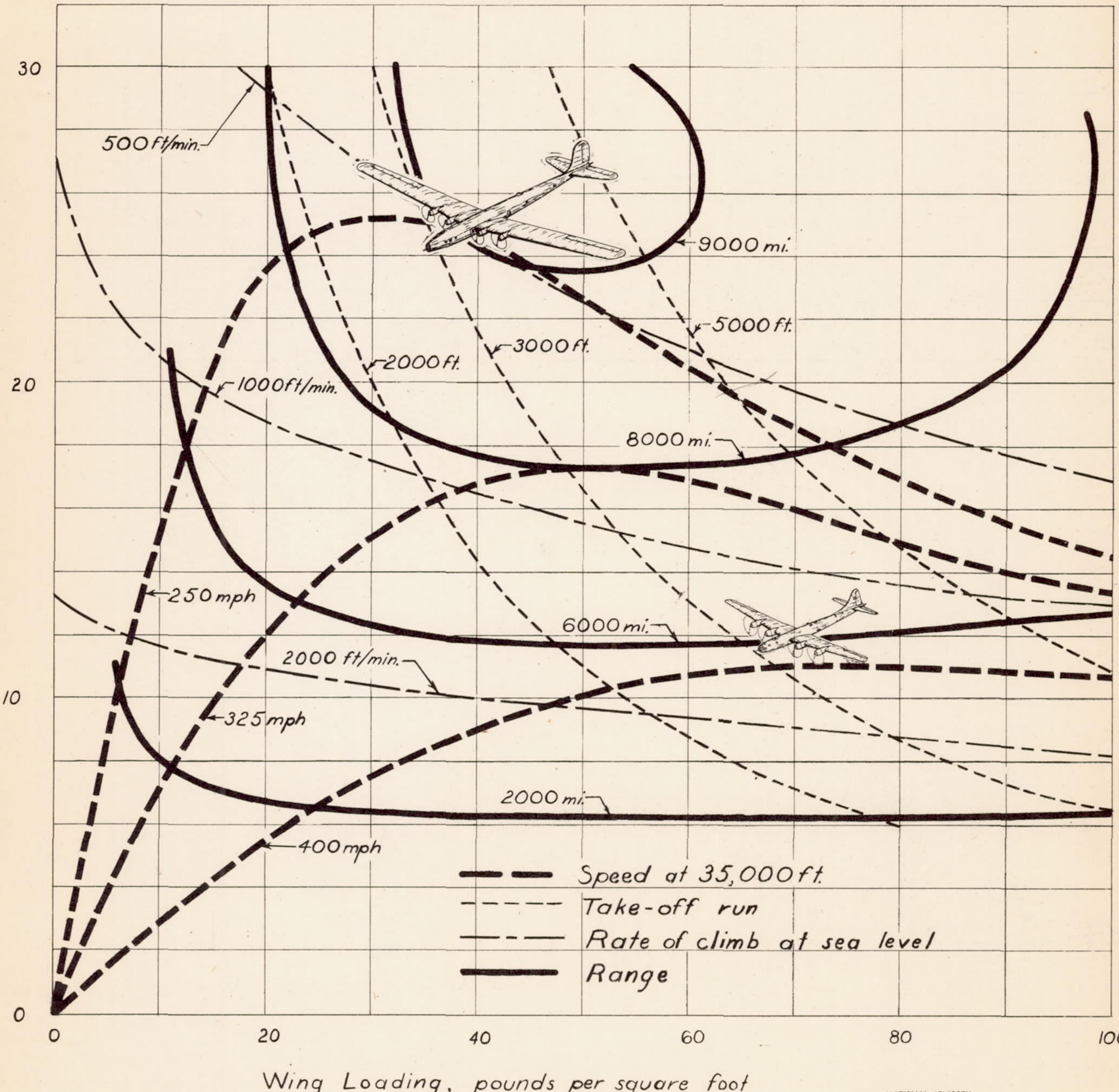

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FIG-1 EFFECT OF POWER LOADING AND WING LOADING ON RANGE, SPEED, RATE OF CLIMB AND TAKE OFF

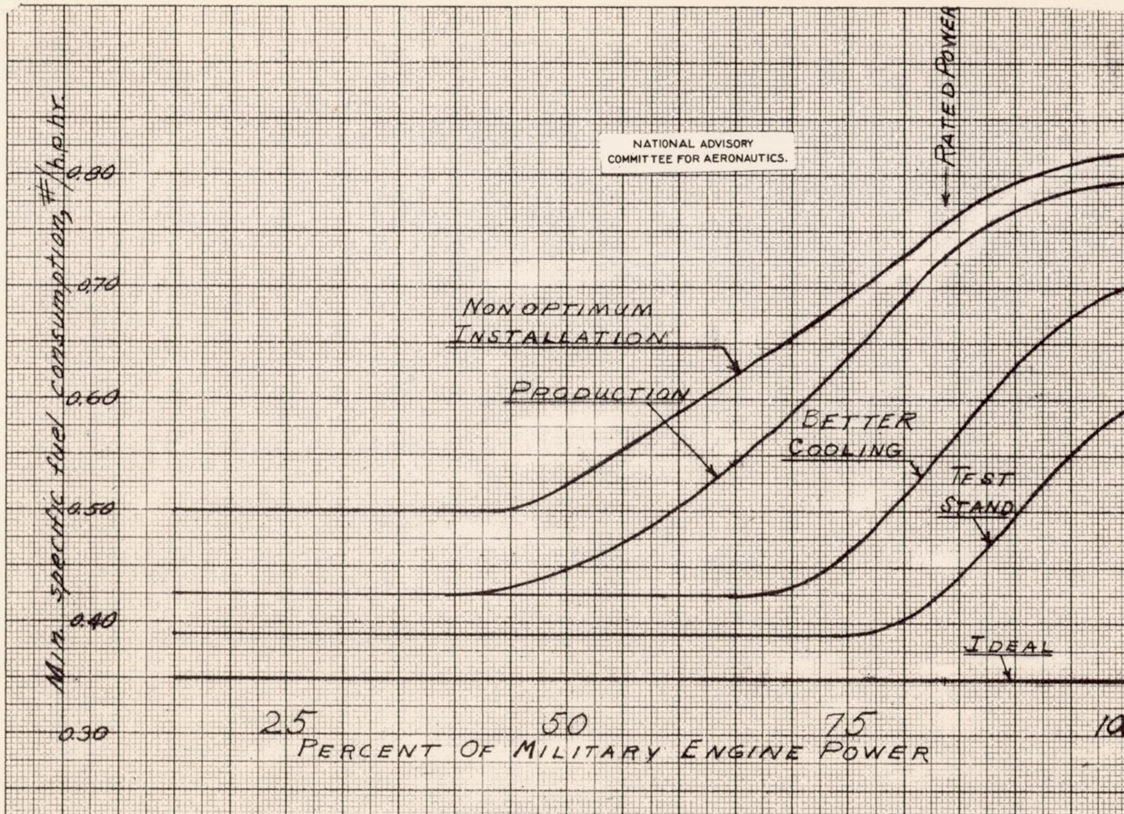

FIGURE 2. VARIATION OF SPECIFIC FUEL CONSUMPTION

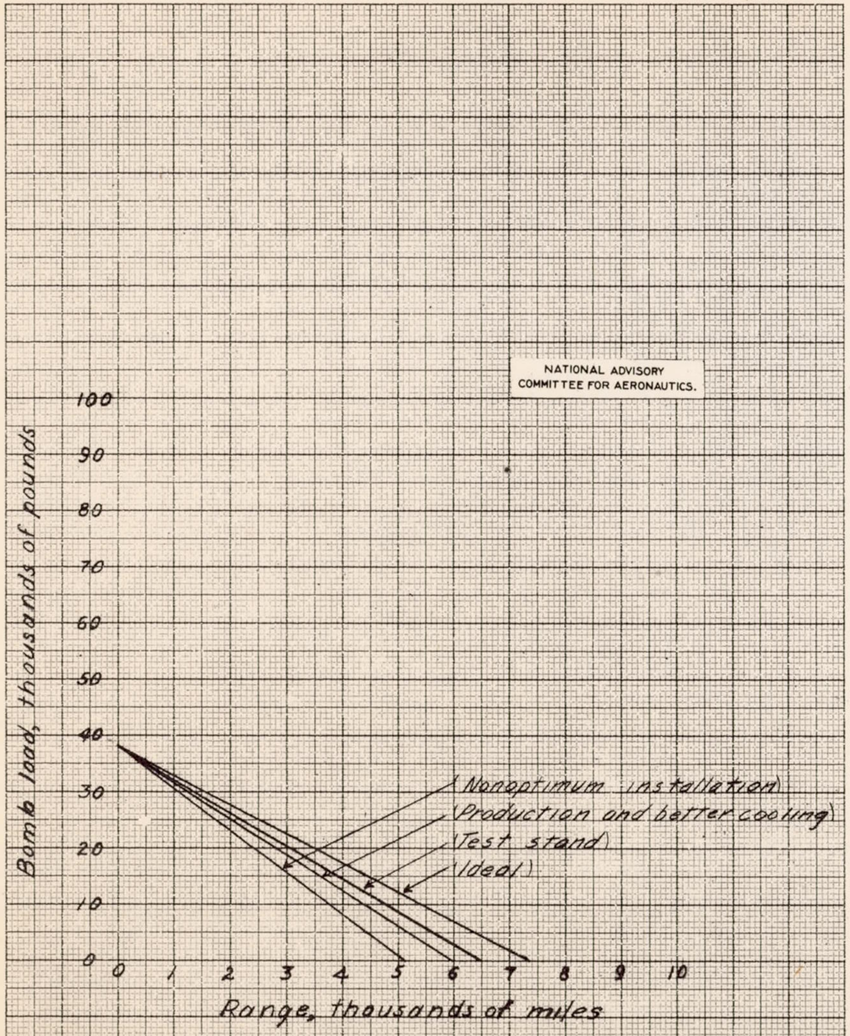

FIG. 3-EFFECT OF SPECIFIC FUEL CONSUMPTION ON RANGE: W/P = 12 ; W/S = 70

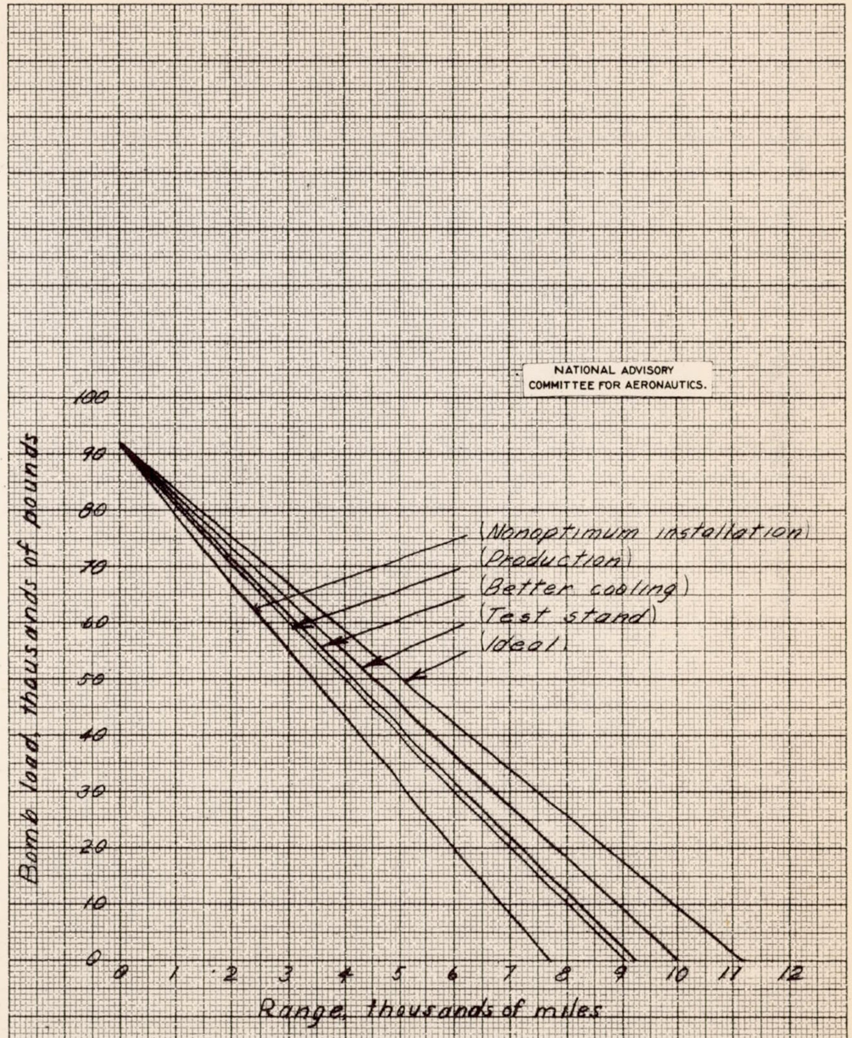

FIG. 4-EFFECT OF SPECIFIC FUEL CONSUMPTION ON RANGE W/P = 25 ; W/S = 40

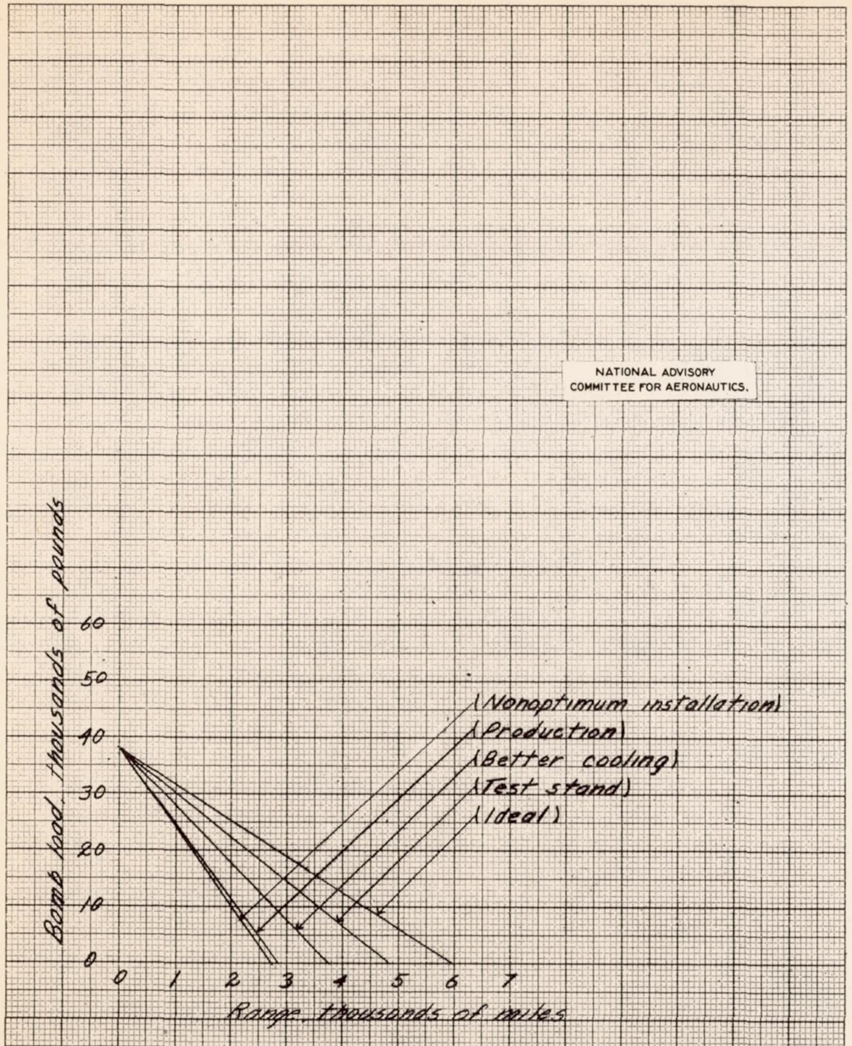

FIG. 5. EFFECT OF FUEL CONSUMPTION ON RANGE AT MAX. CONTINUOUS RATED POWER. W/P = 12 ; W/S = 70

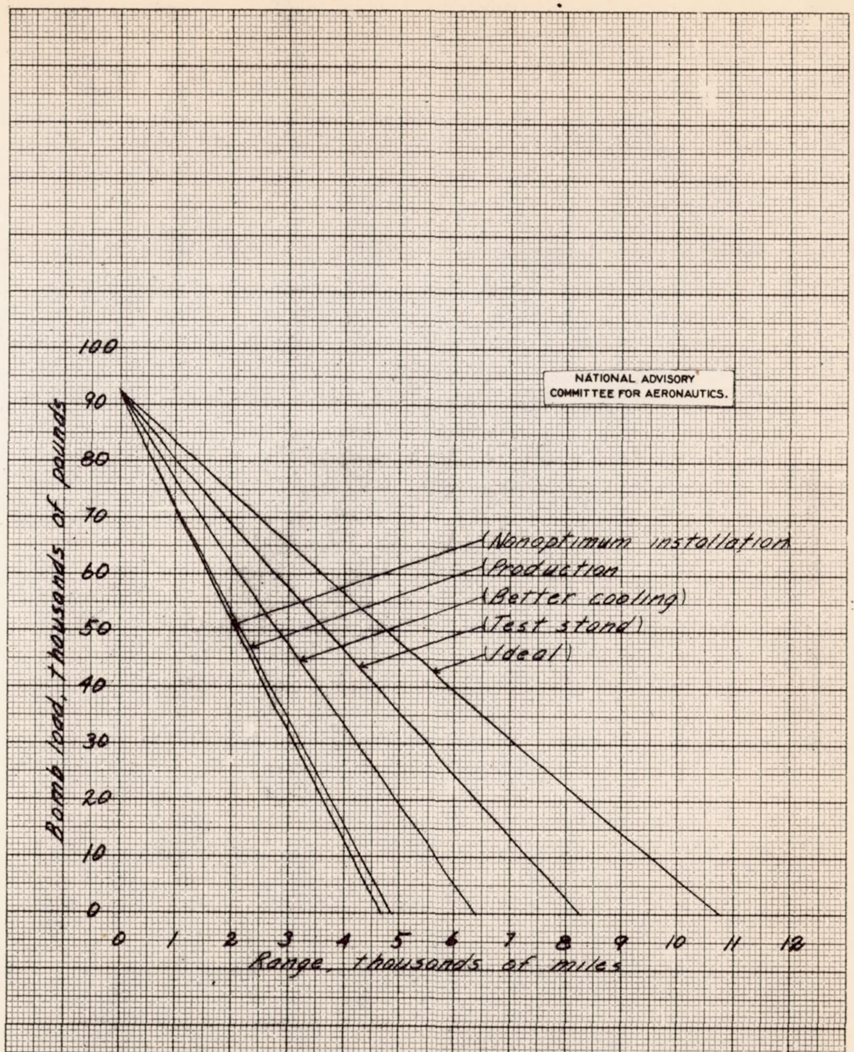

FIG. 6 - EFFECT OF FUEL CONSUMPTION ON RANGE AT MAX. CONTINUOUS RATED POWER. W/P = 25 ; W/S = 40

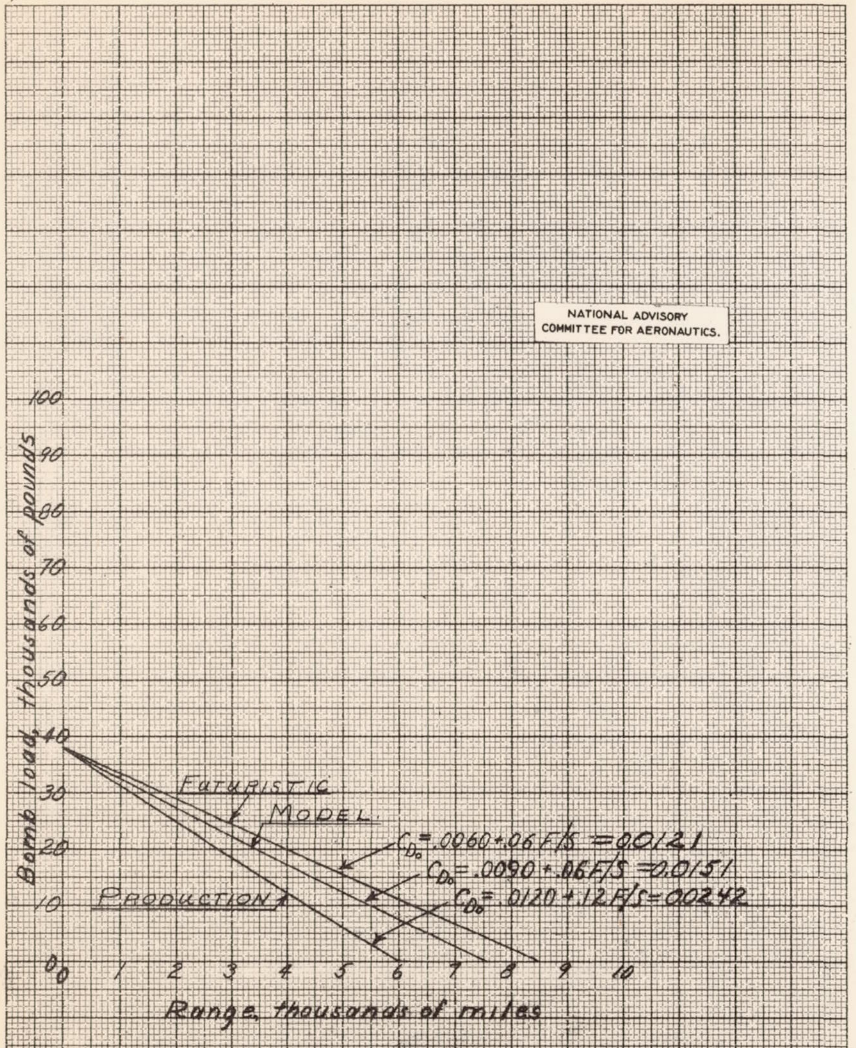

FIG. 7 - EFFECT OF AERODYNAMIC CLEANLINESS ON RANGE; W/P = 12 ; W/S = 70

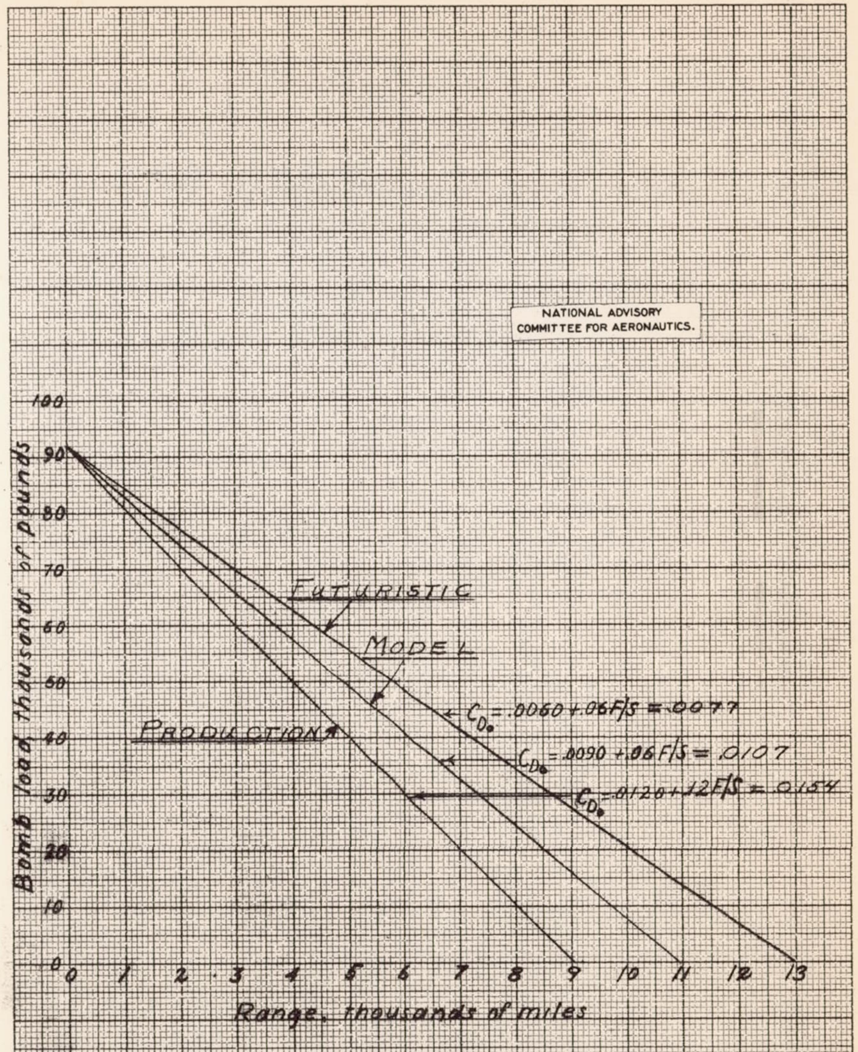

FIG. 8 - EFFECT OF AERODYNAMIC CLEANLINESS ON RANGE; W/P = 25 W/S = 40

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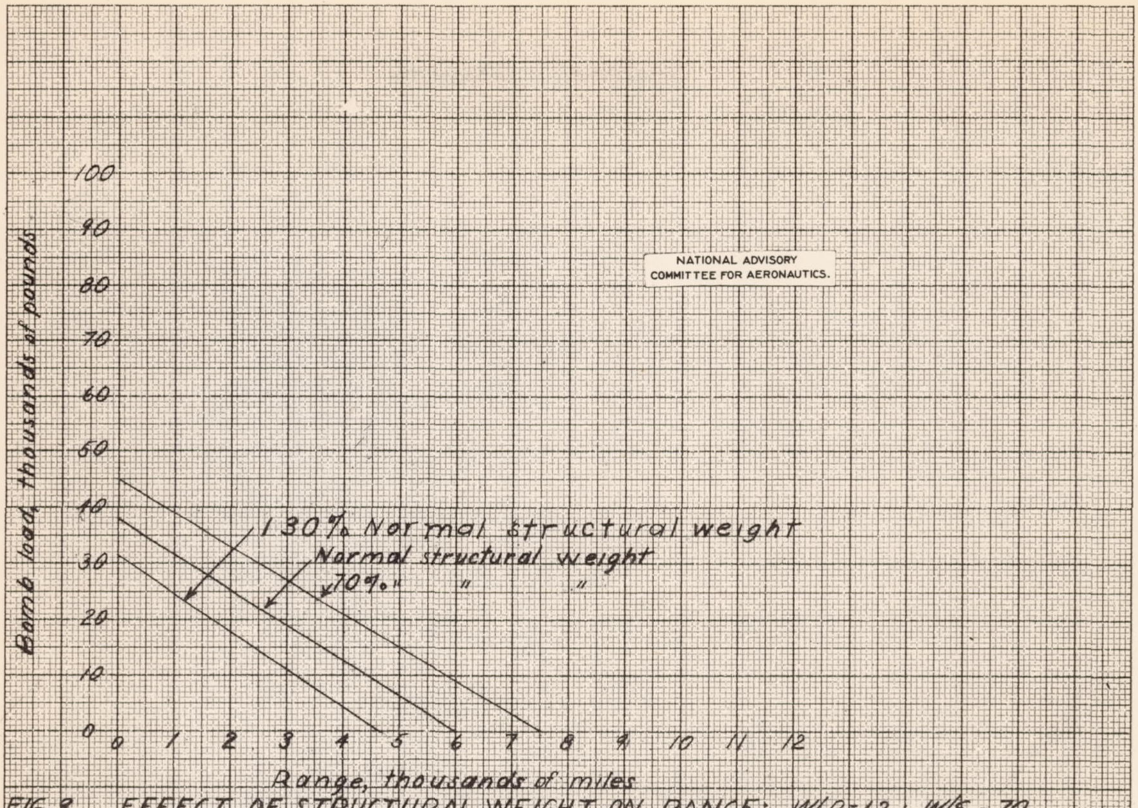

FIG. 9 EFFECT OF STRUCTURAL WEIGHT ON RANGE; W/P=12; W/S=70

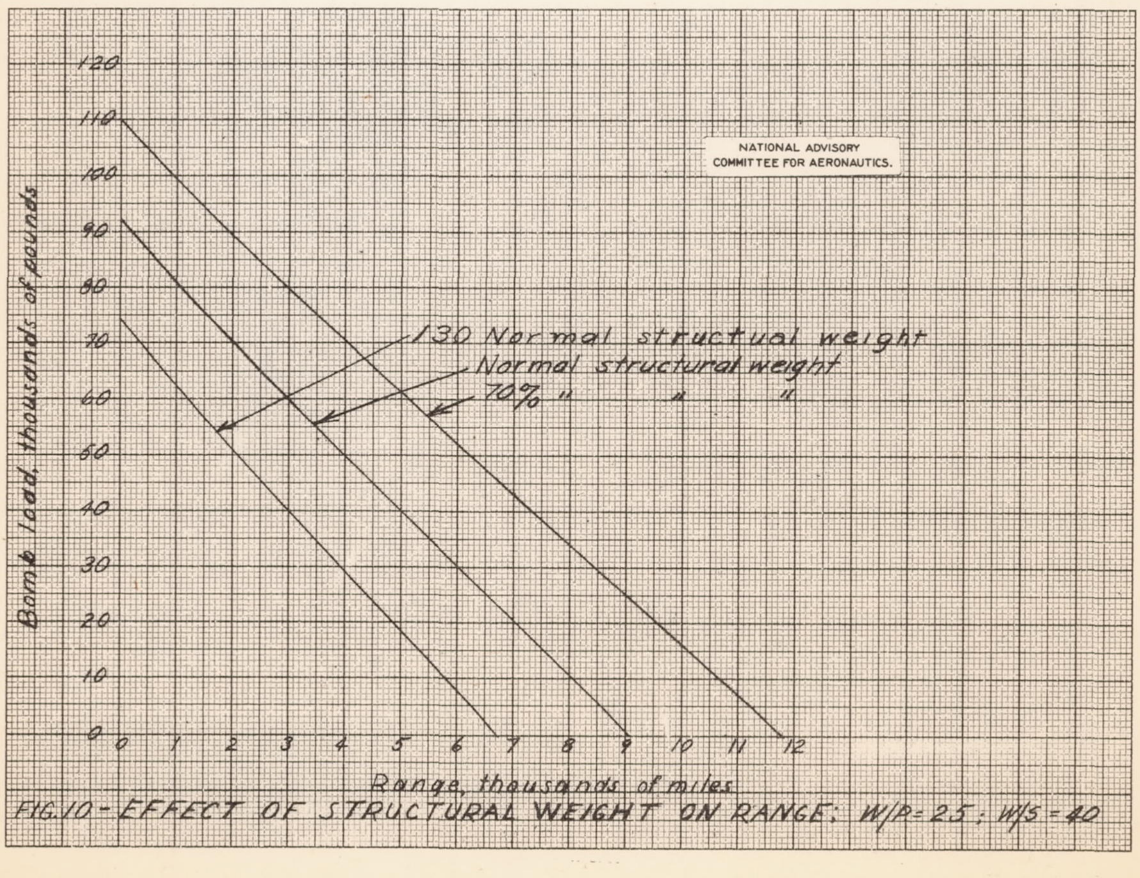

FIG. 10 - EFFECT OF STRUCTURAL WEIGHT ON RANGE: W/P=25; W/S=40

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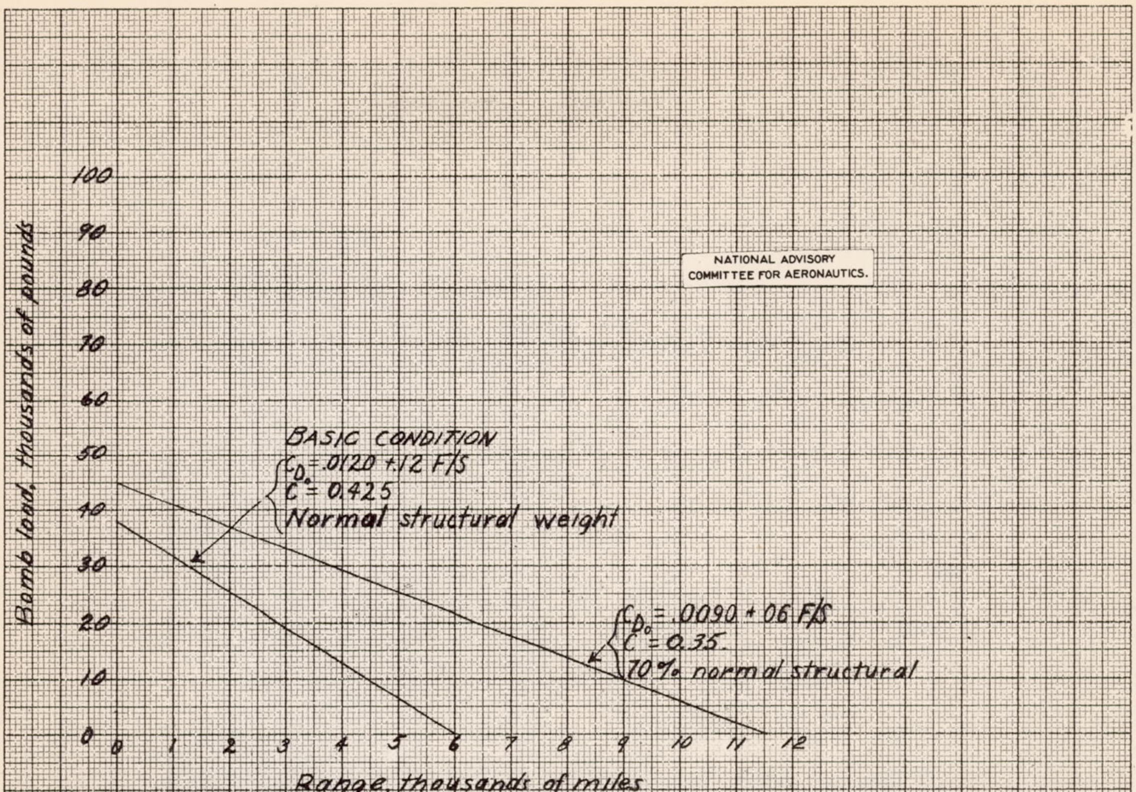

FIG. 11 – COMBINED EFFECT OF SPECIFIC FUEL CONSUMPTION, AERODYNAMIC CLEANLINESS, AND STRUCTURAL WEIGHT ON RANGE; W/P = 12; W/S = 70

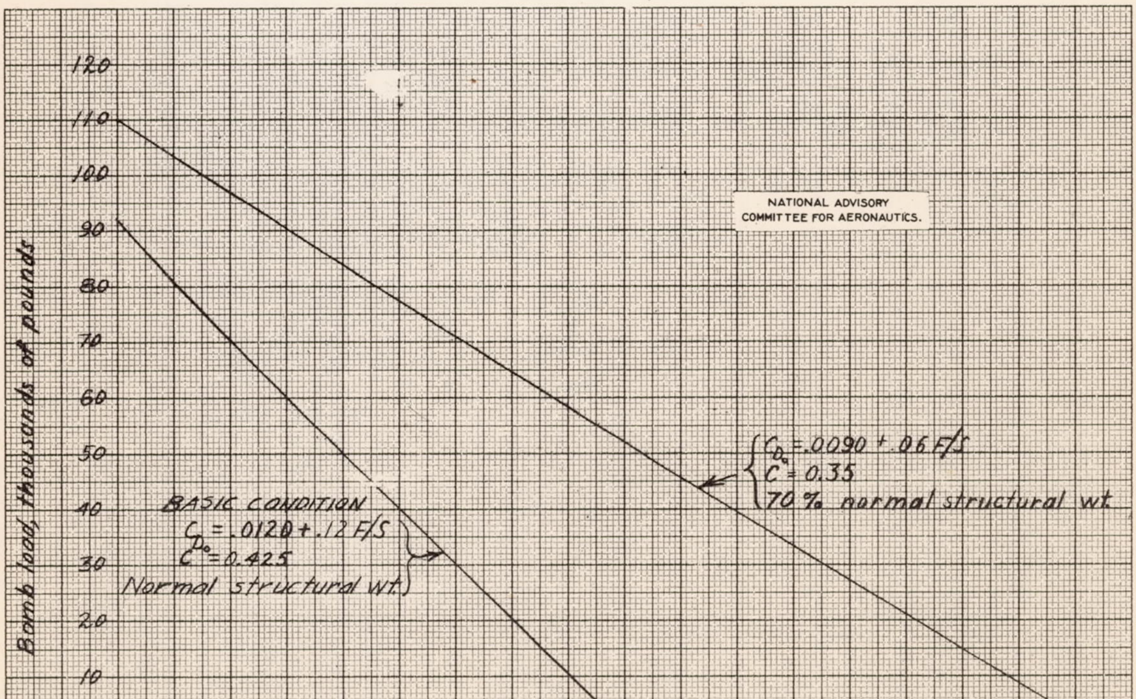

FIG. 12 – COMBINED EFFECT OF SPECIFIC FUEL CONSUMPTION, AERODYNAMIC CLEANLINESS, AND STRUCTURAL WEIGHT ON RANGE; W/P = 25; W/S = 40

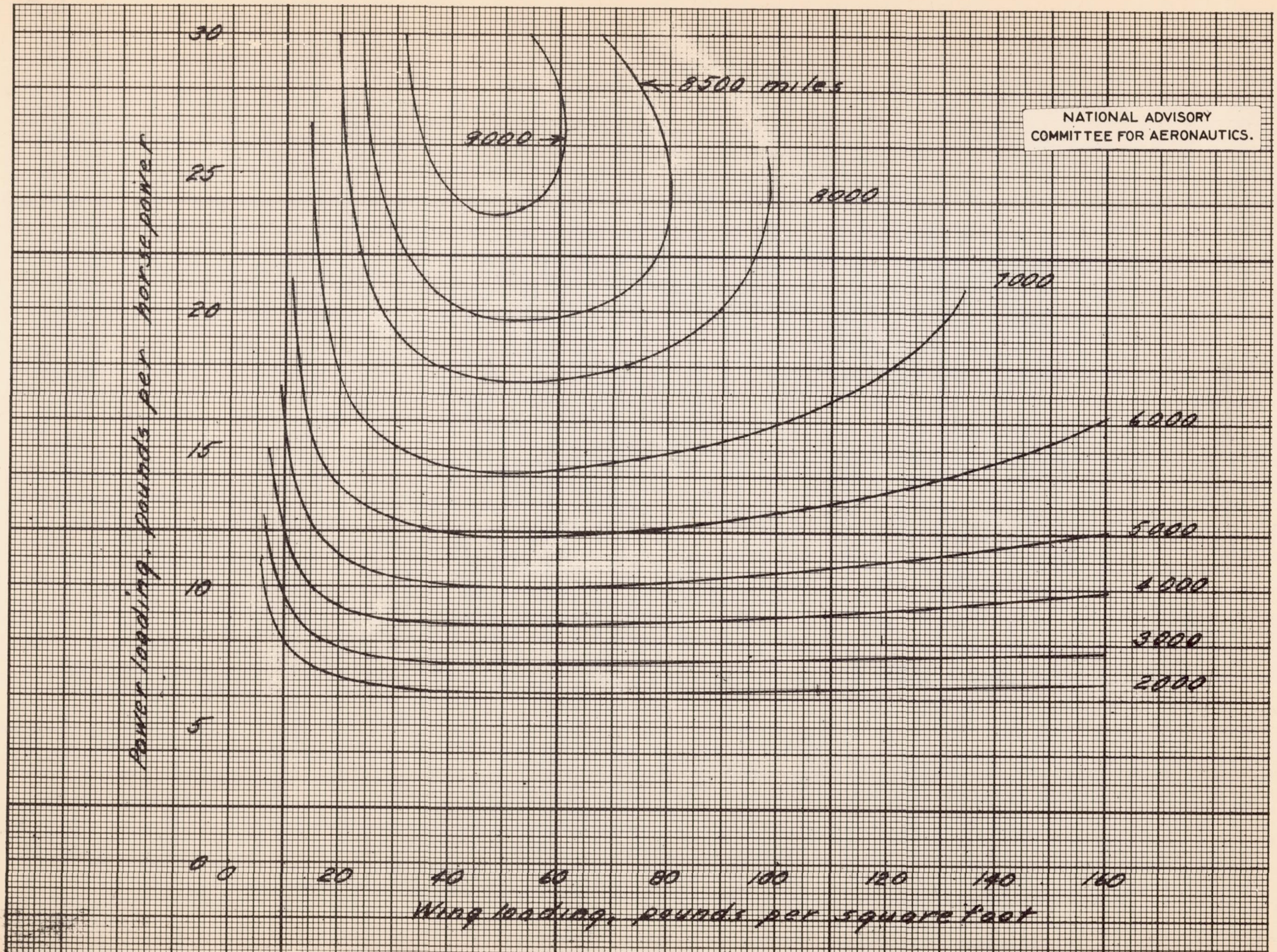

FIG. 13 a. RANGE CHART FOR "BASIC CONDITION"

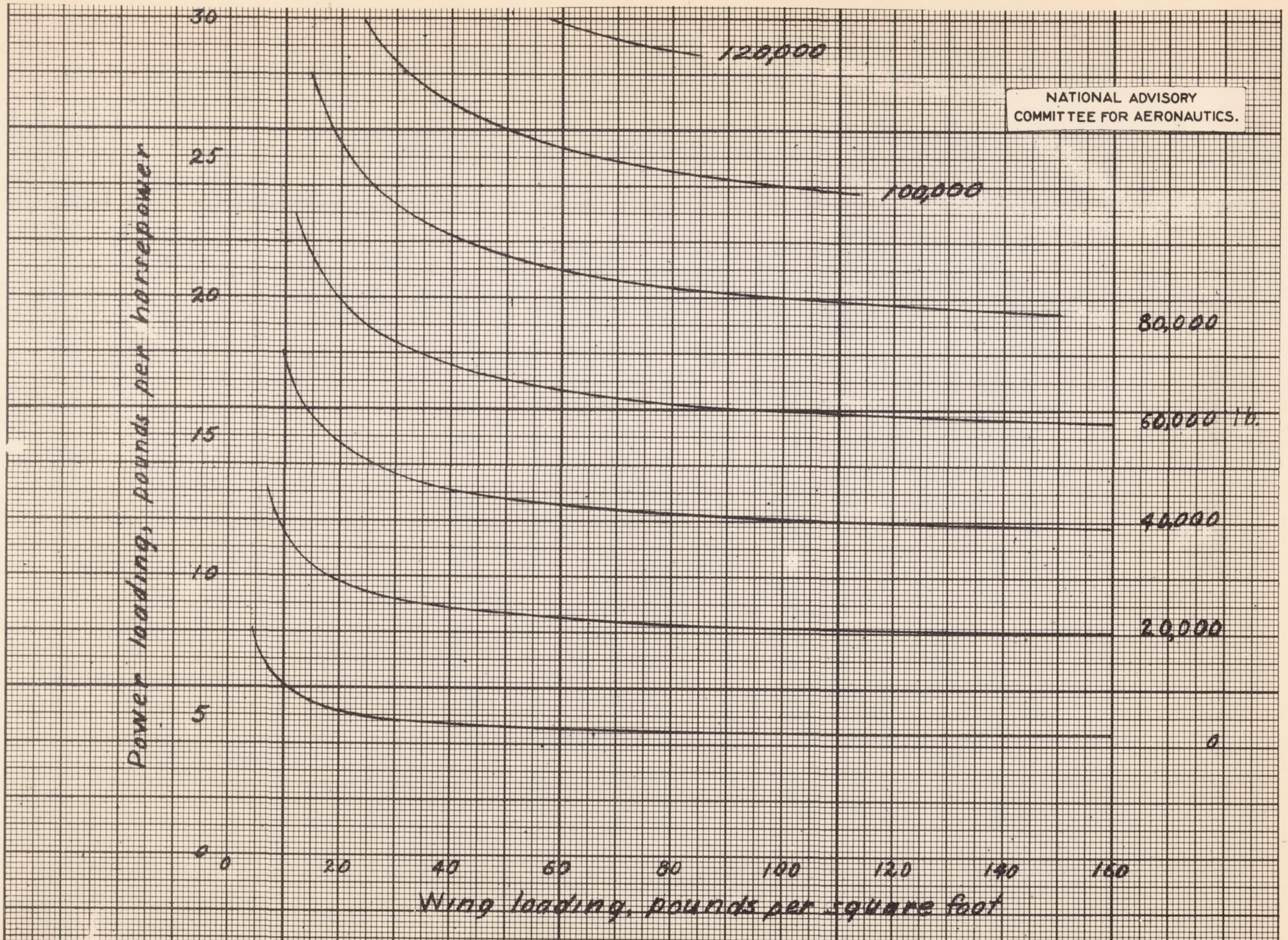

FIG. 13 b DISPOSABLE LOAD WITH NORMAL STRUCTURAL WEIGHT

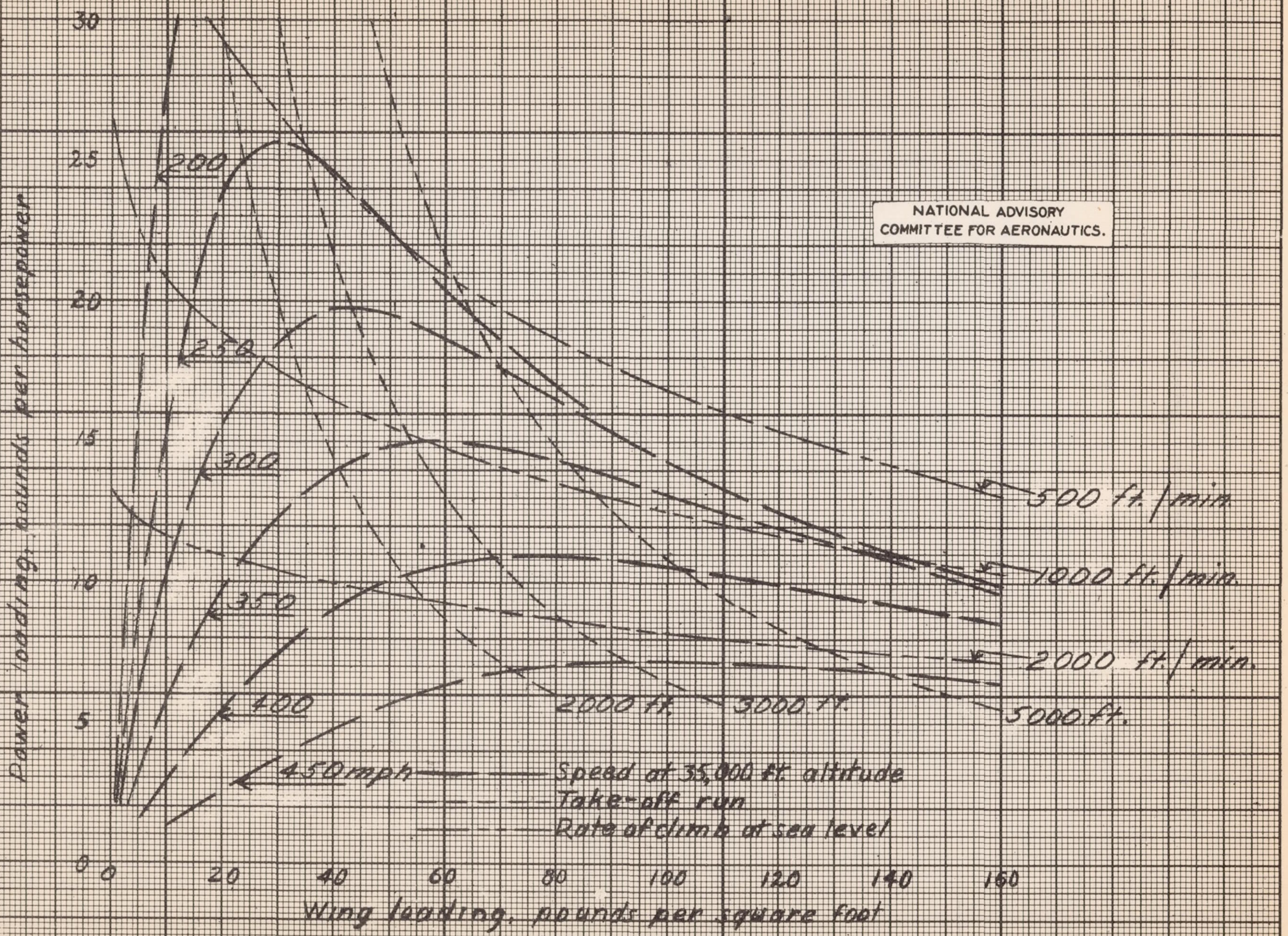

FIG. 13a SPEED, RATE OF CLIMB, TAKE-OFF RUN FOR "BASIC CONDITION".

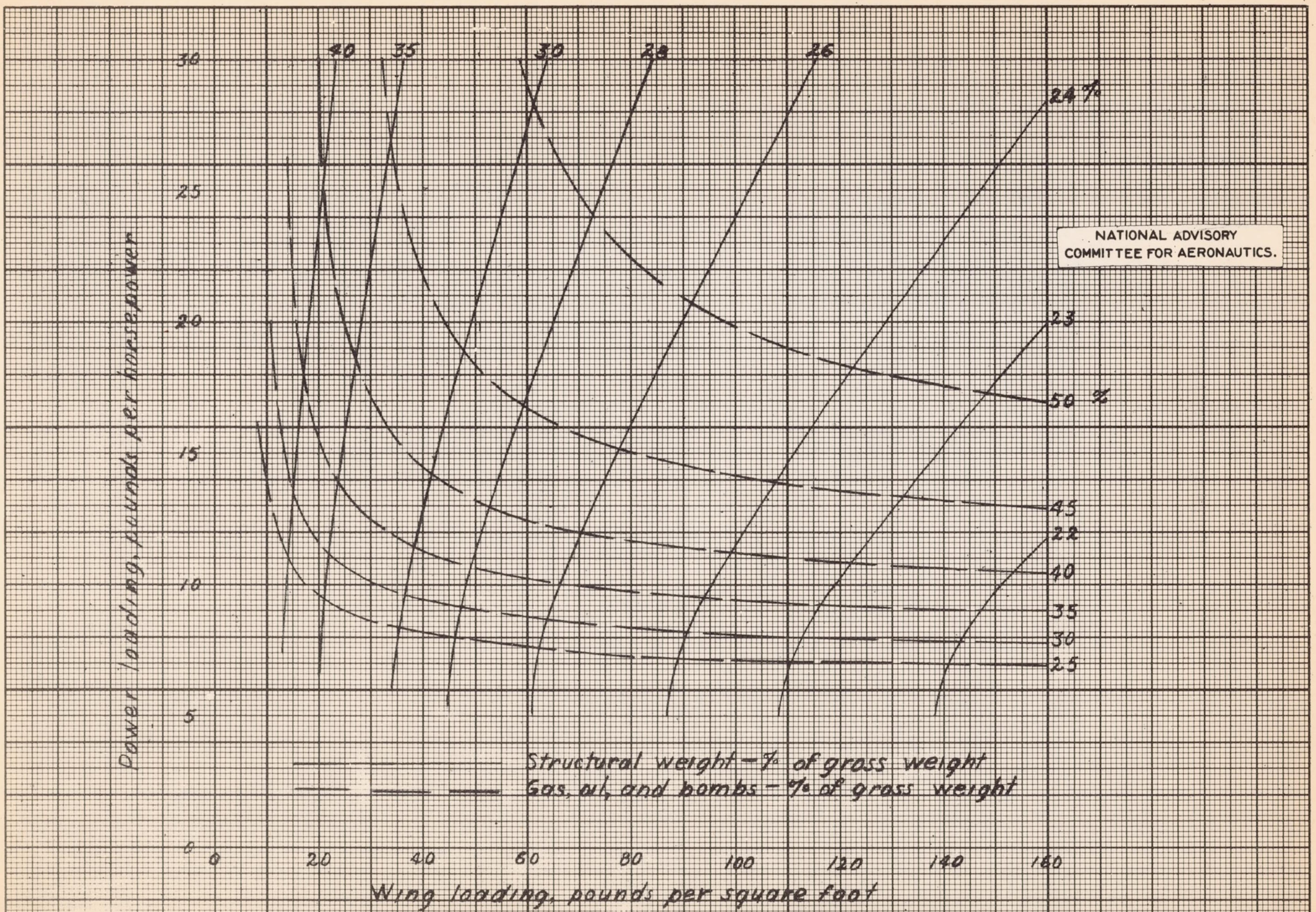

FIG. 13 d WEIGHT CHART FOR BASIC CONDITION

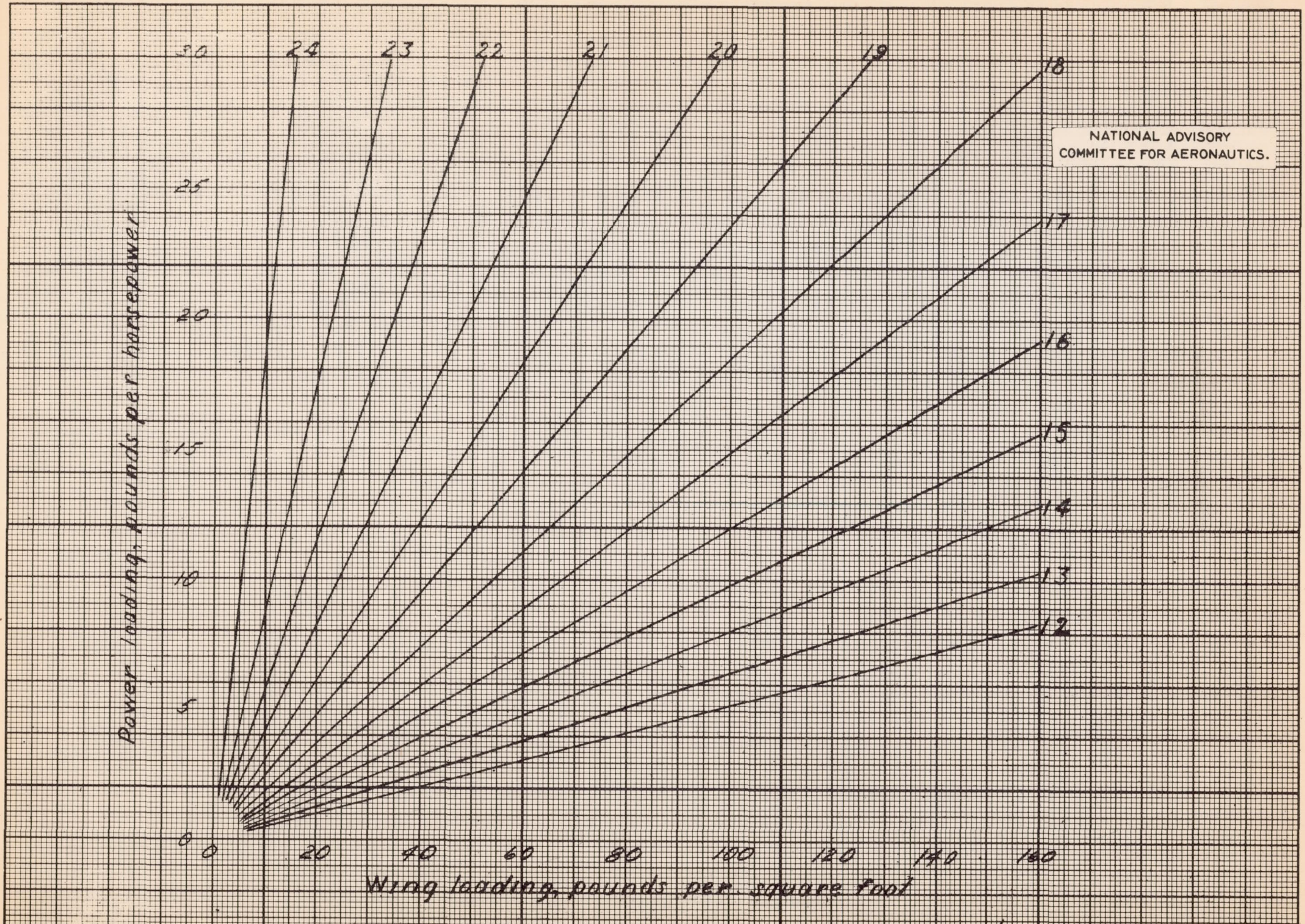

FIG. 13 e MAXIMUM LIFT-TO-DRAG RATIO: $C_{D_0} = .0120 + 0.12\ f/S$ BASIC CONDITION

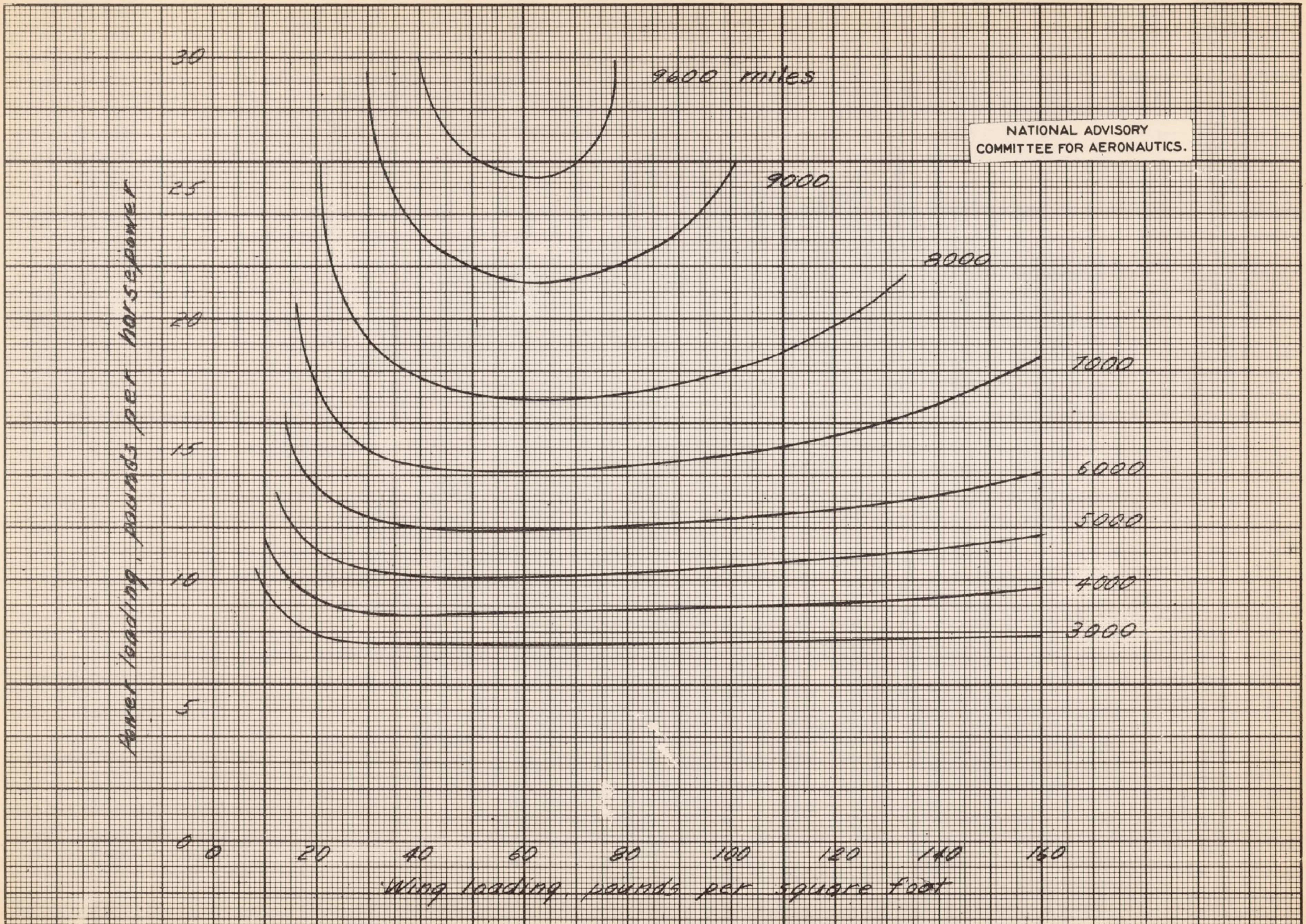

FIG. 14- RANGE CHART USING "BETTER COOLING" SPECIFIC FUEL CONSUMPTION CURVE.

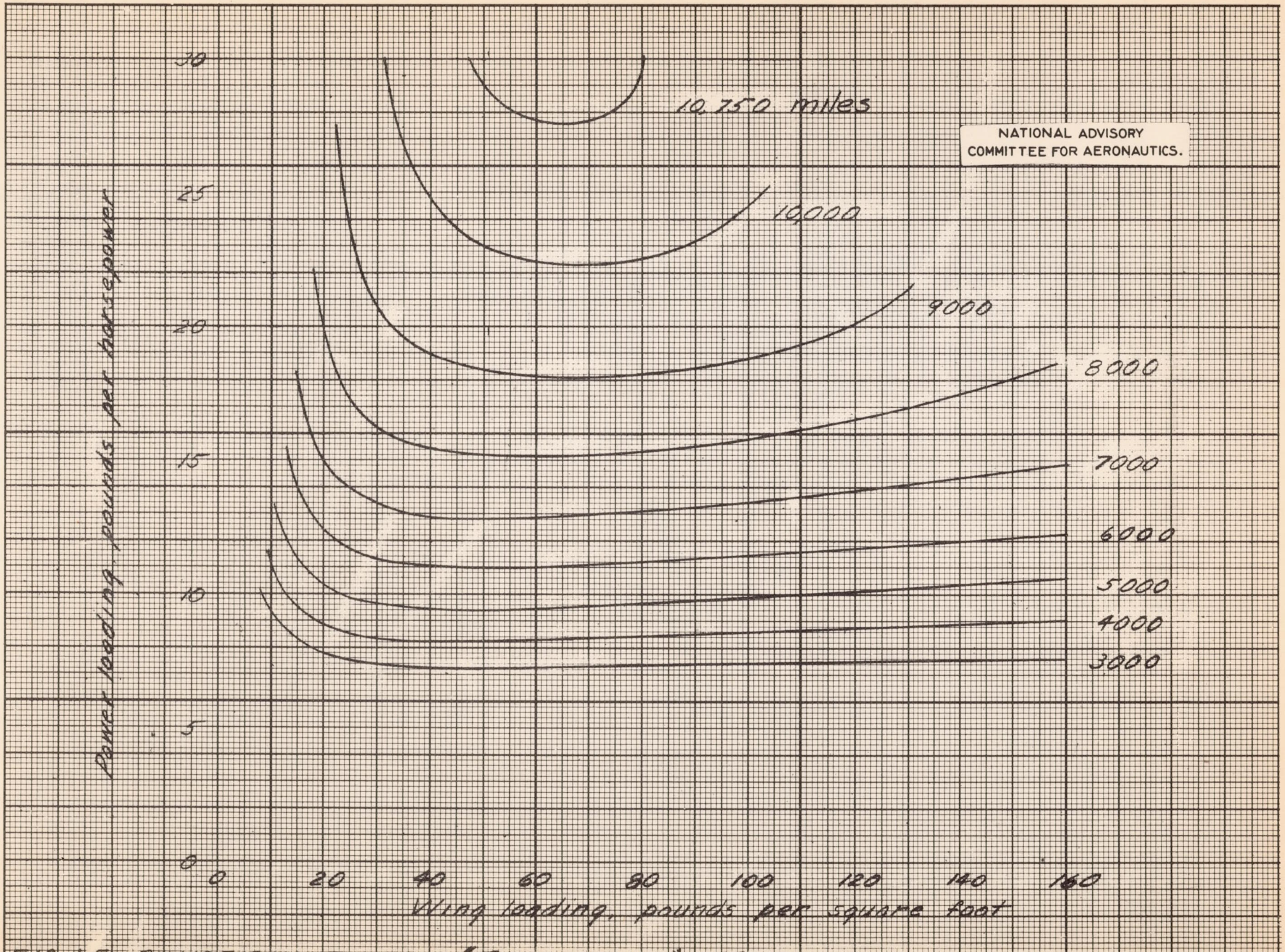

FIG. 15 RANGE CHART USING "TEST STAND" SPECIFIC FUEL CONSUMPTION CURVE

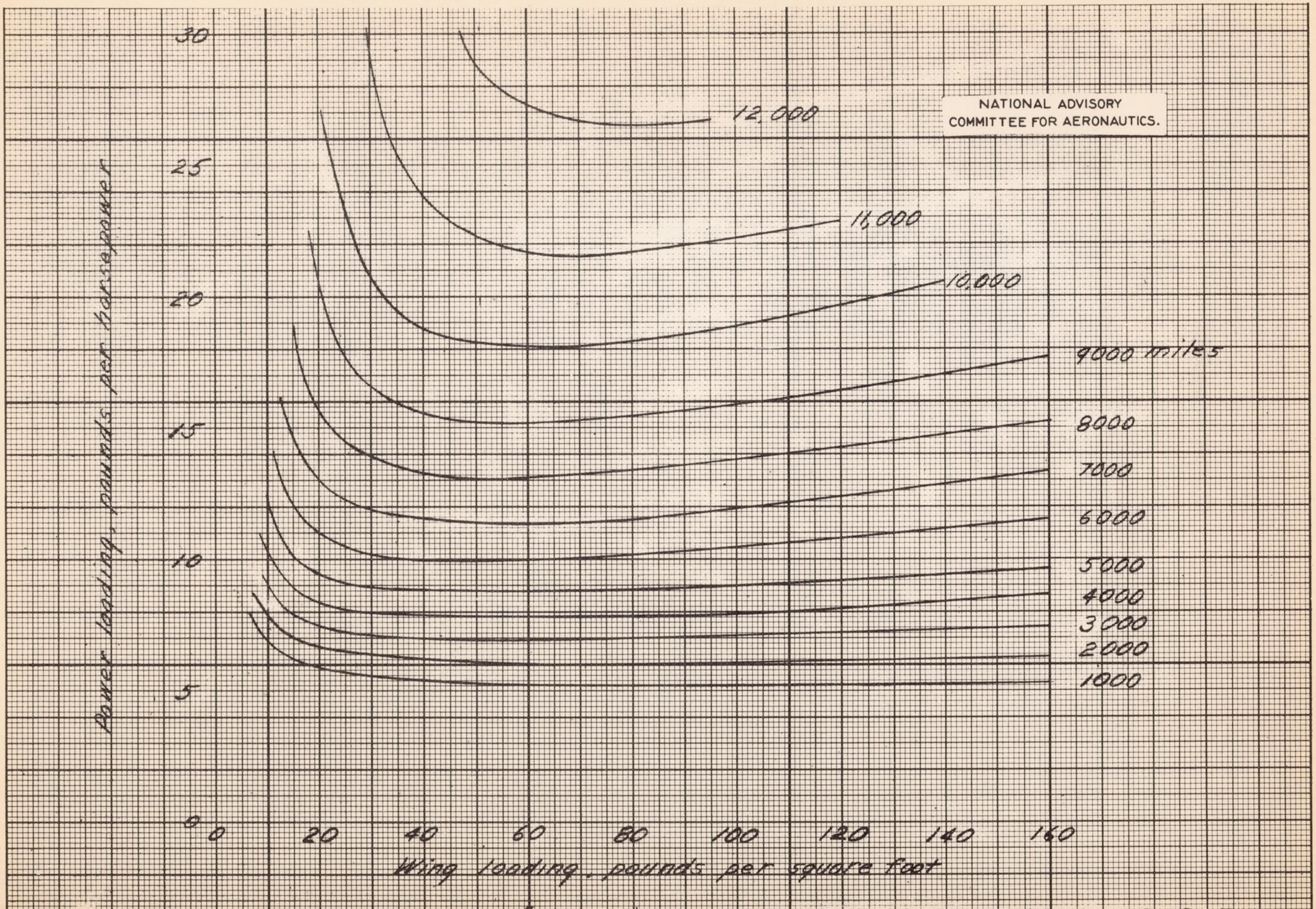

FIG.16 — RANGE CHART USING 'IDEAL' SPECIFIC FUEL CONSUMPTION CURVE.

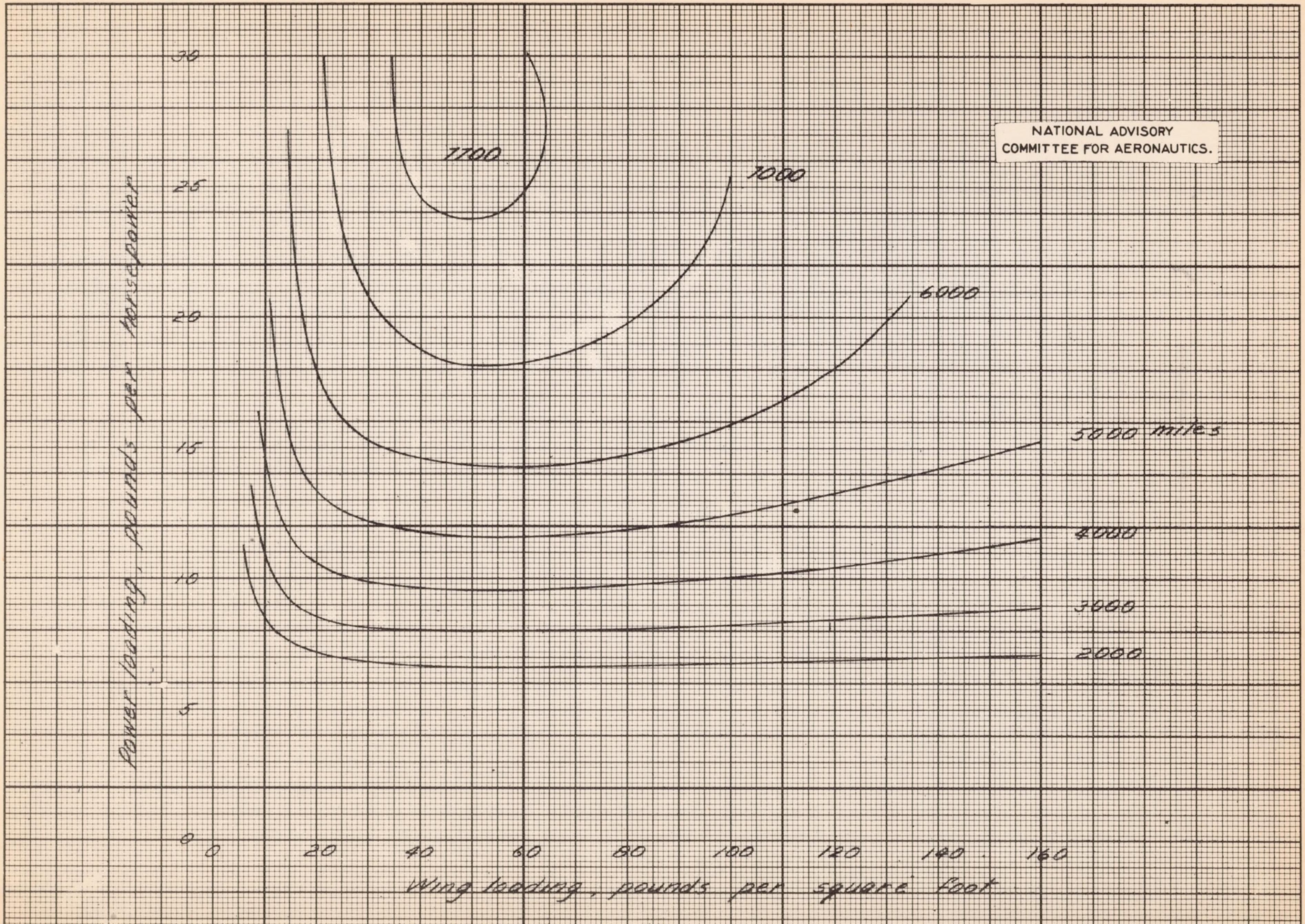

FIG. 17 RANGE CHART USING "NONOPTIMUM" SPECIFIC FUEL CONSUMPTION CURVE

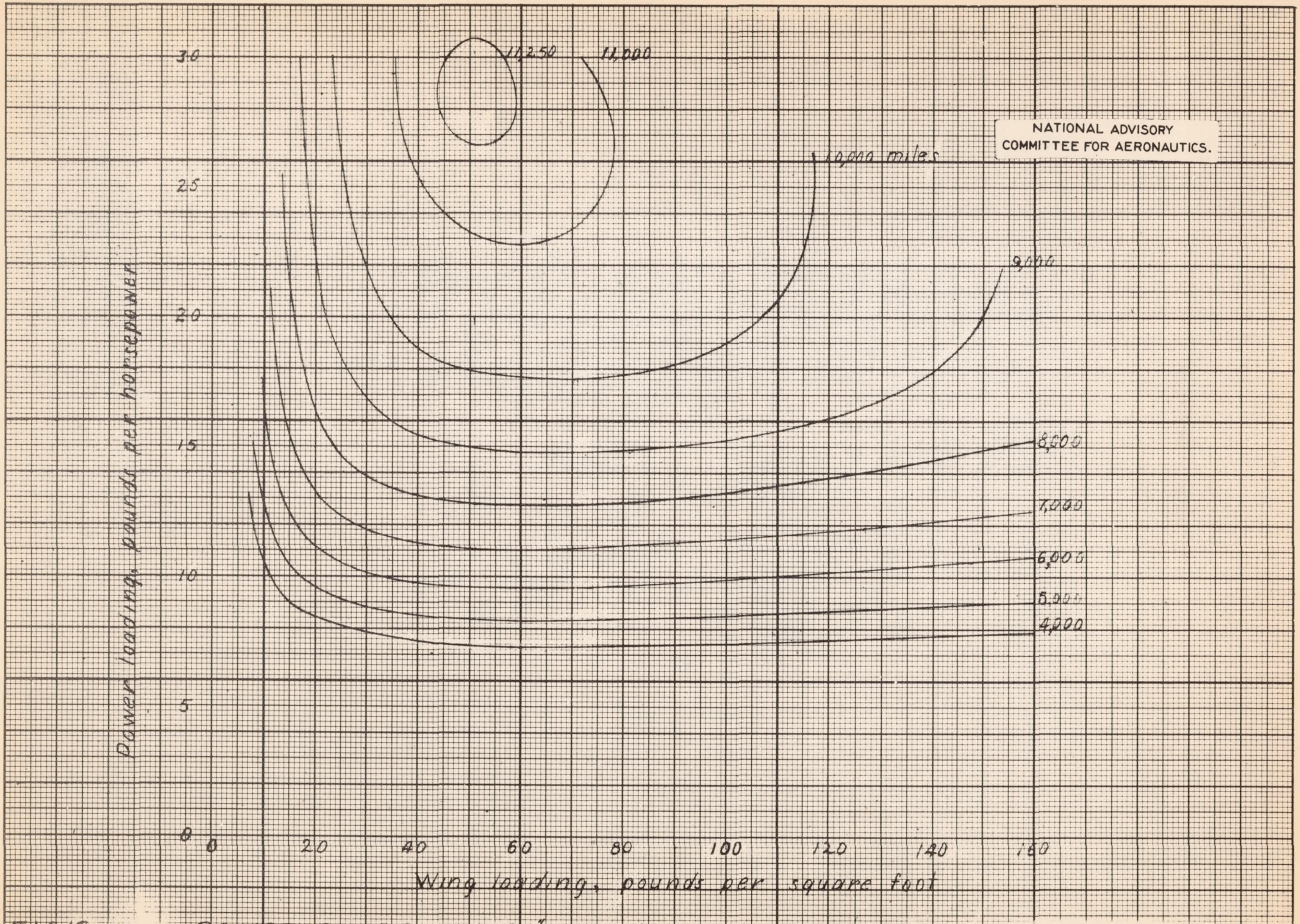

FIG.18a RANGE CHART USING "MODEL" DRAG COEFFICIENT

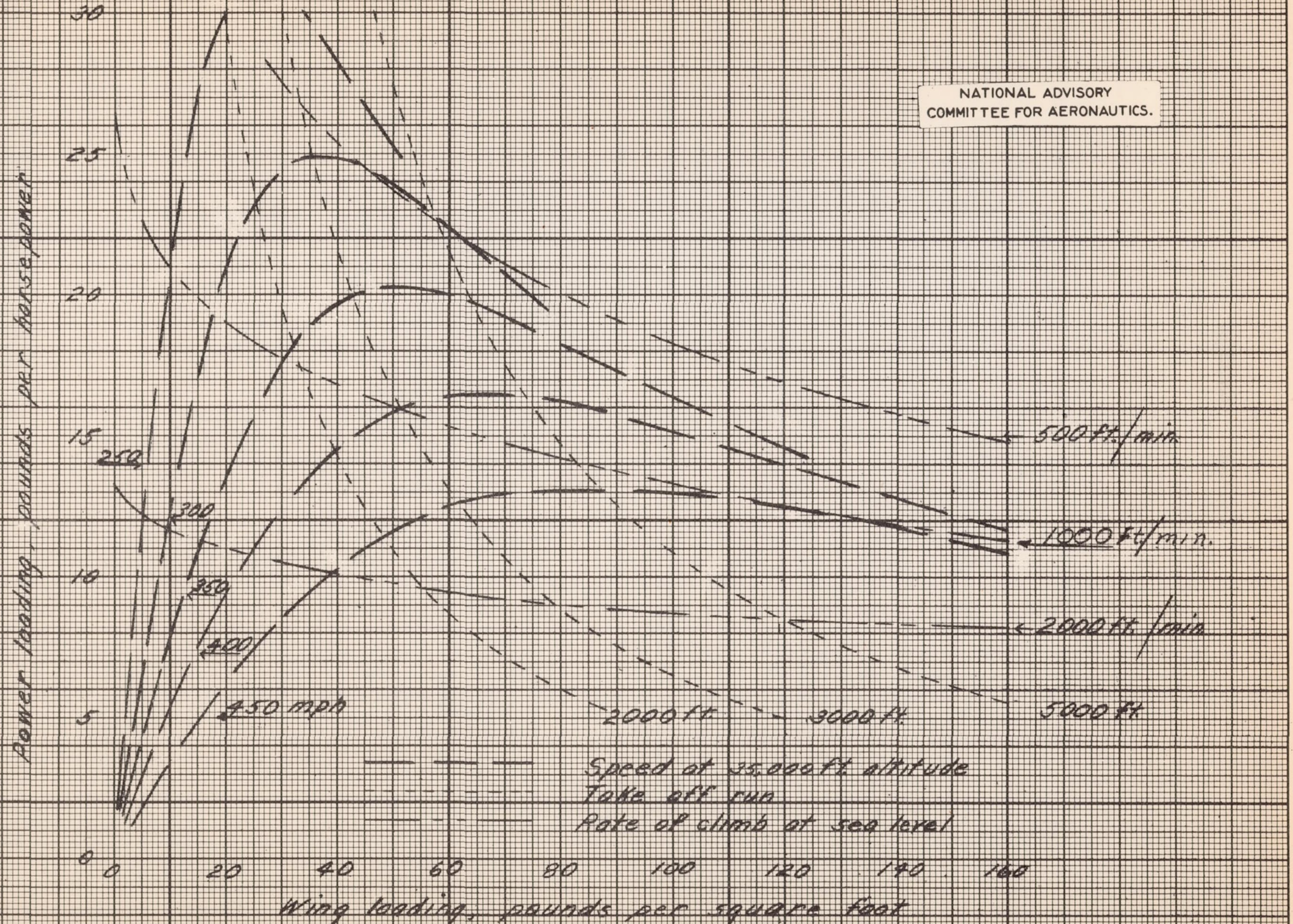

FIG 18b SPEED, RATE OF CLIMB, TAKE-OFF RUN USING "MODEL" DRAG COEFFICIENT

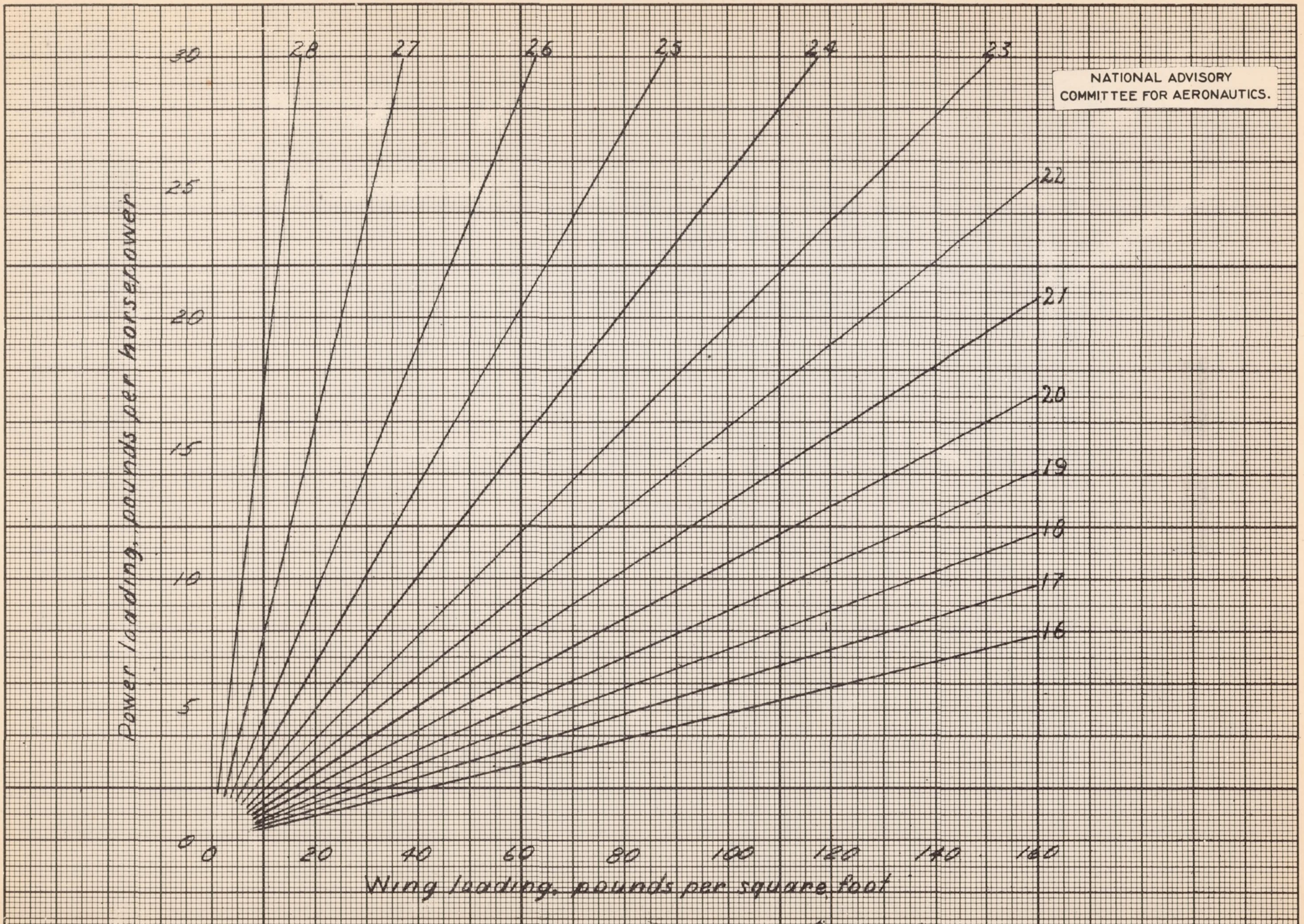

FIG. 18 C MAXIMUM LIFT-TO-DRAG RATIO: "MODEL" DRAG COEFFICIENT.

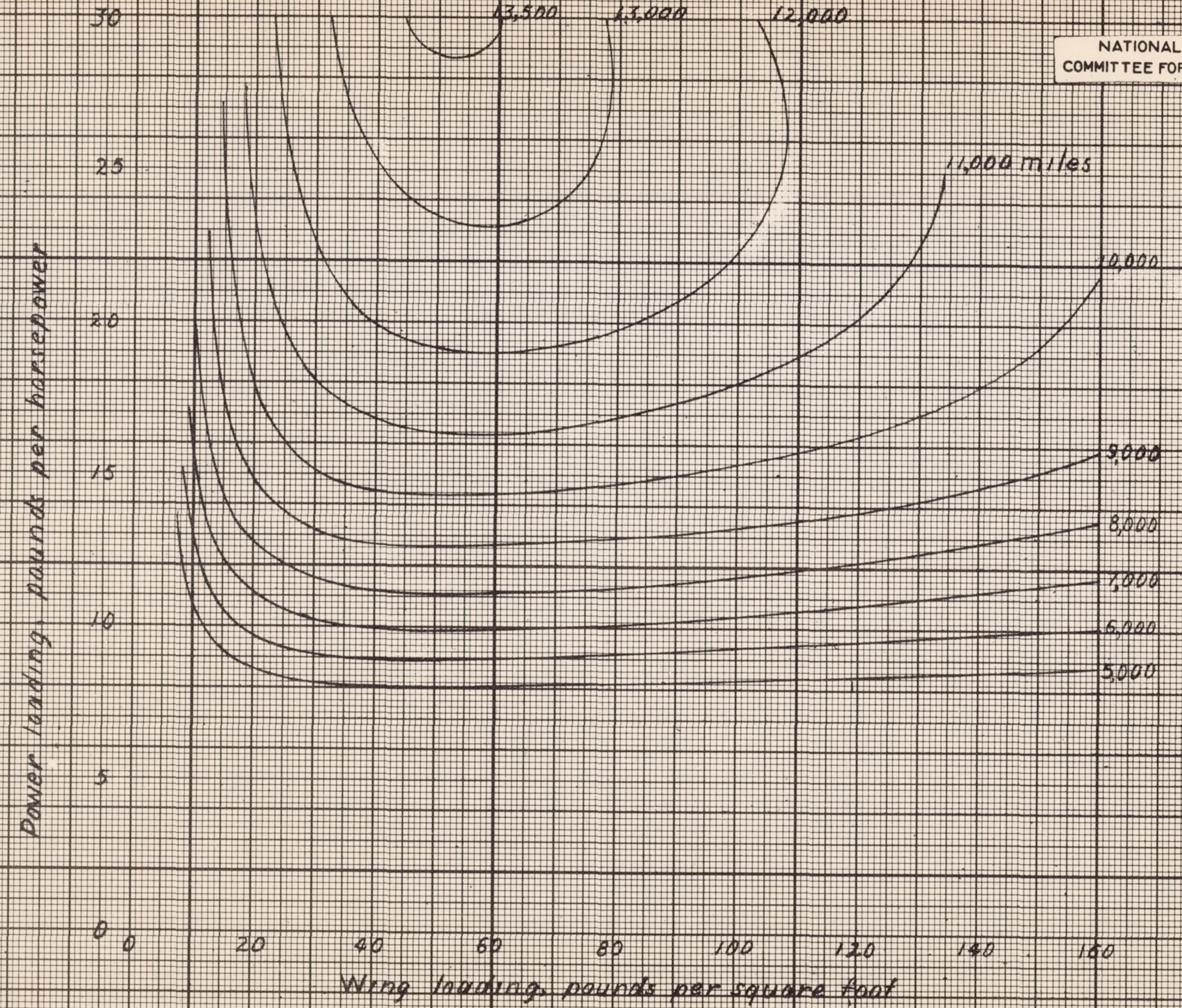

FIG. 19a RANGE CHART USING "FUTURISTIC" DRAG COEFFICIENT.

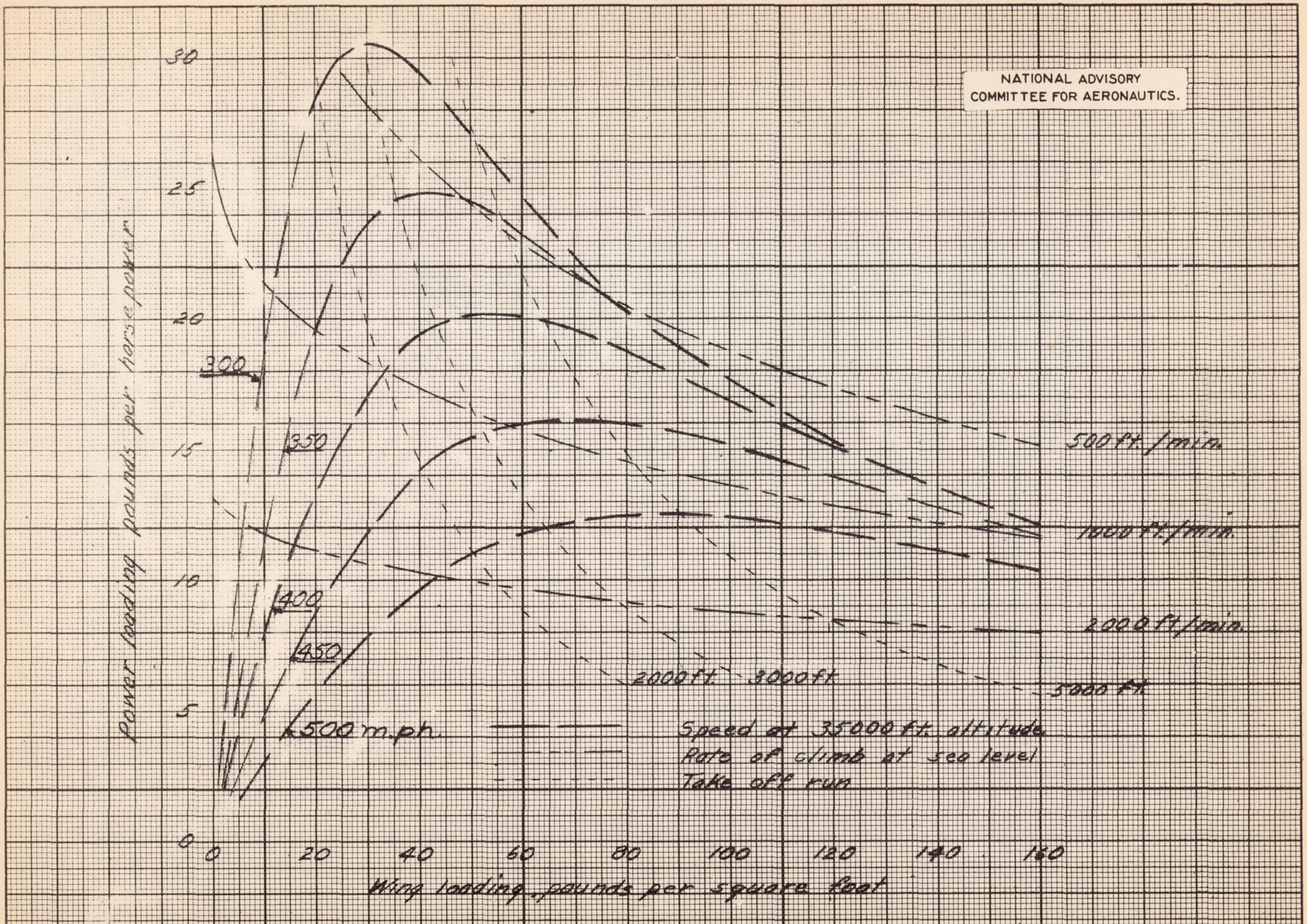

FIG. 19 b SPEED, RATE OF CLIMB, TAKE-OFF RUN: "FUTURISTIC" DRAG COEFFICIENT.

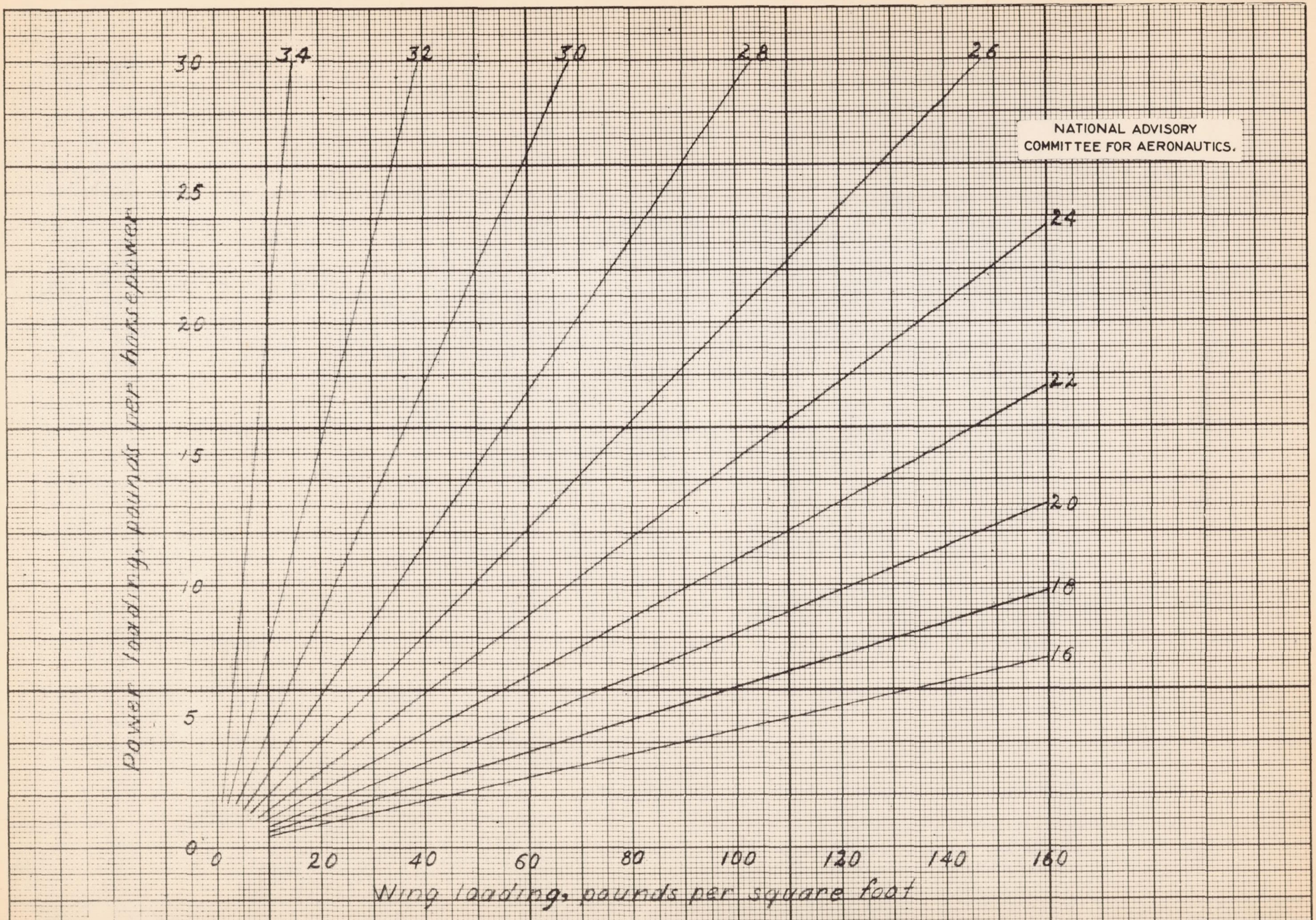

FIG. 19 b. MAXIMUM LIFT-TO-DRAG RATIOS USING "FUTURISTIC" DRAG COEFFICIENT.

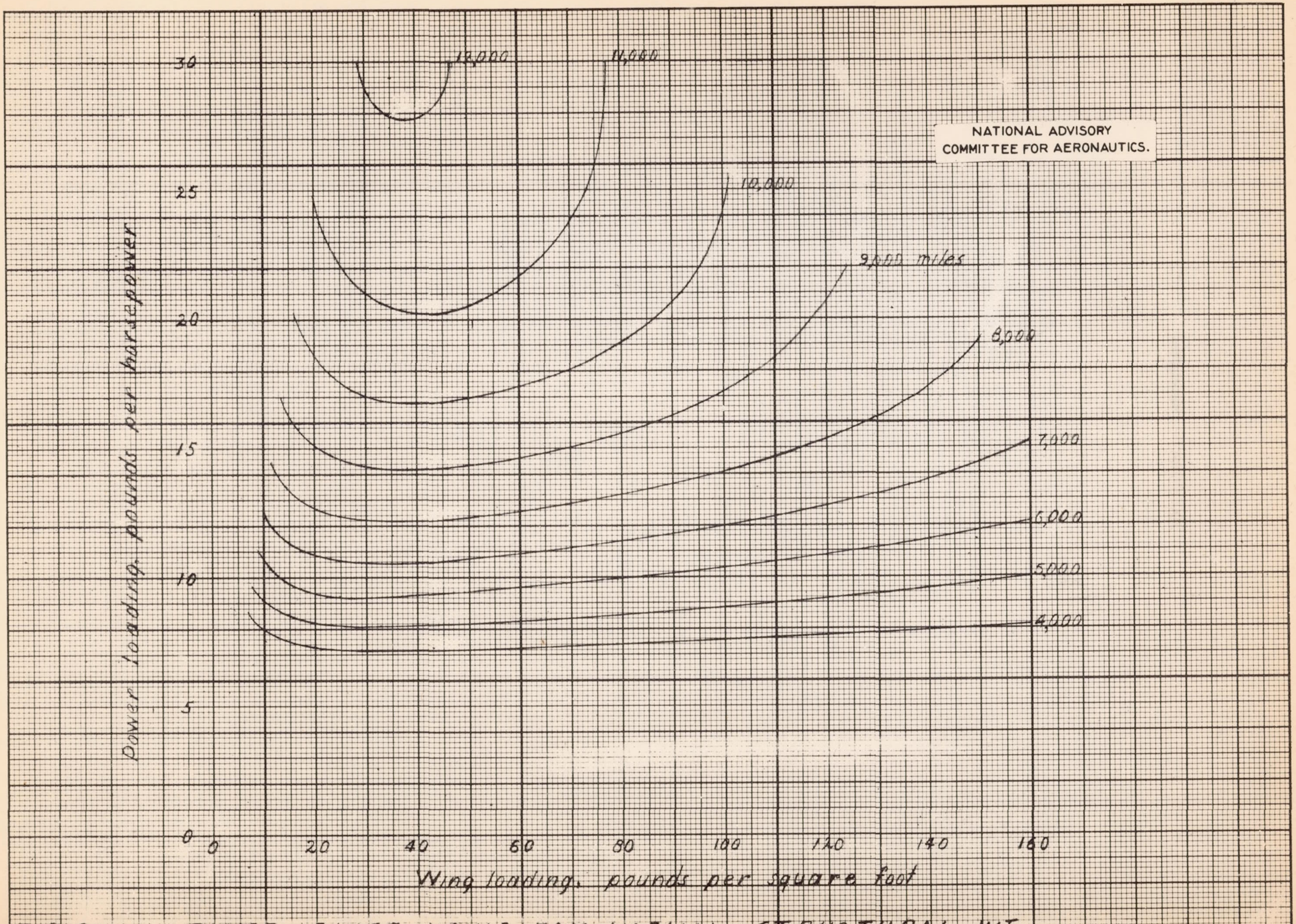

FIG. 20a RANGE CHART USING 70% NORMAL STRUCTURAL WT.

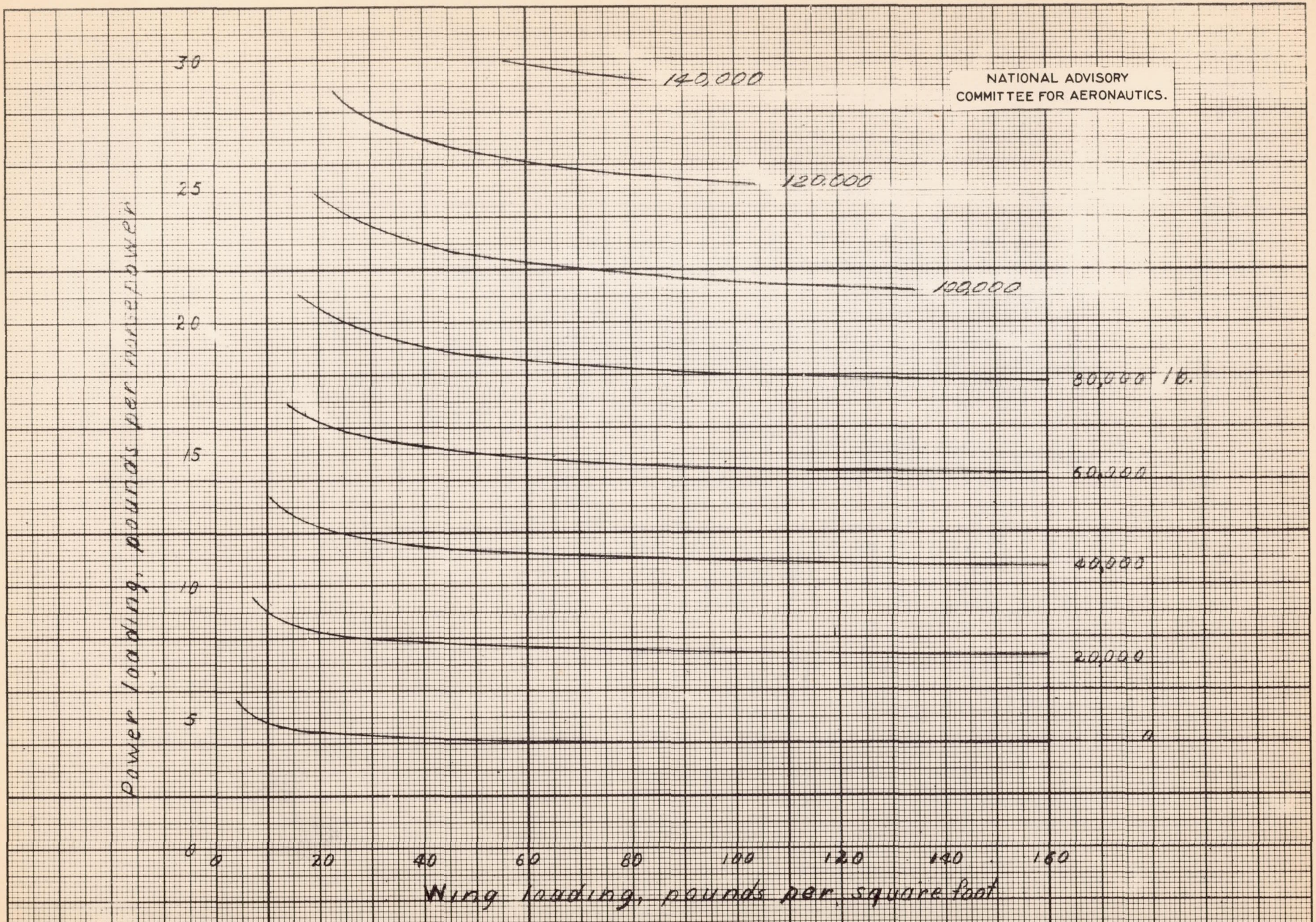

FIG. 20-b DISPOSABLE LOAD WITH 70% NORMAL STRUCTURAL WEIGHT

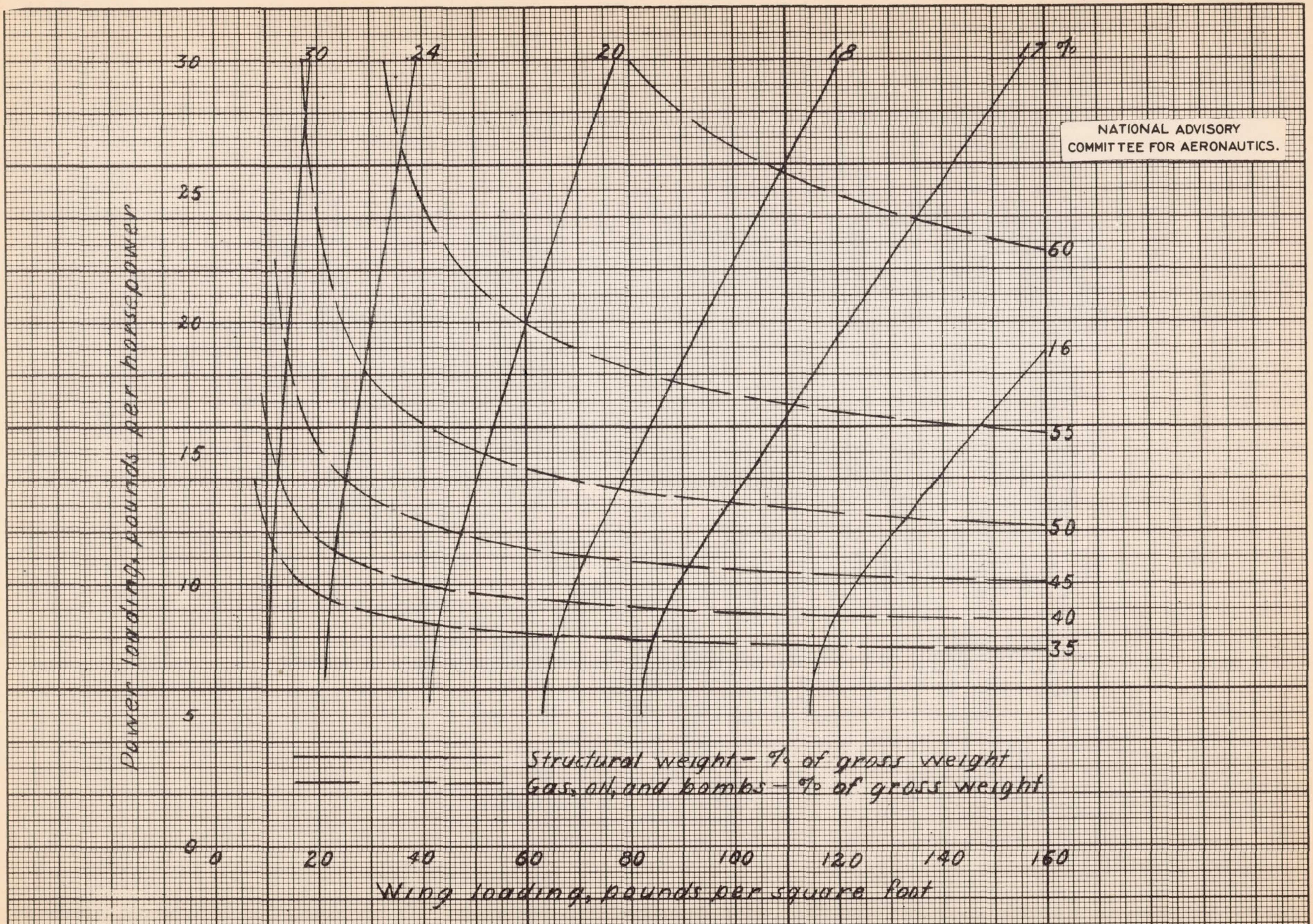

FIG. 20C WEIGHT CHART FOR 70% NORMAL STRUCTURAL WEIGHT

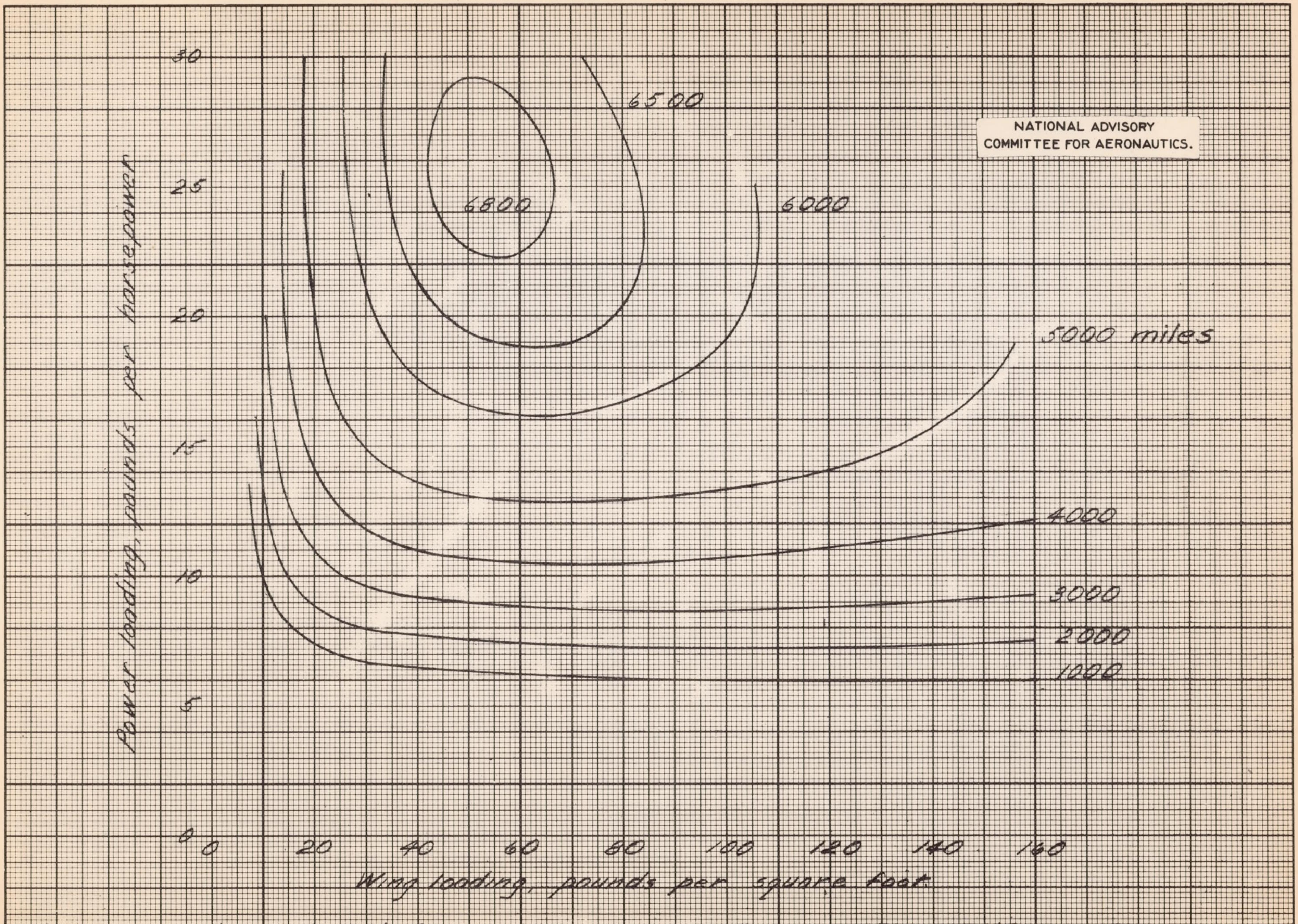

FIG 21 a - RANGE CHART USING 130% NORMAL STRUCTURAL WT.

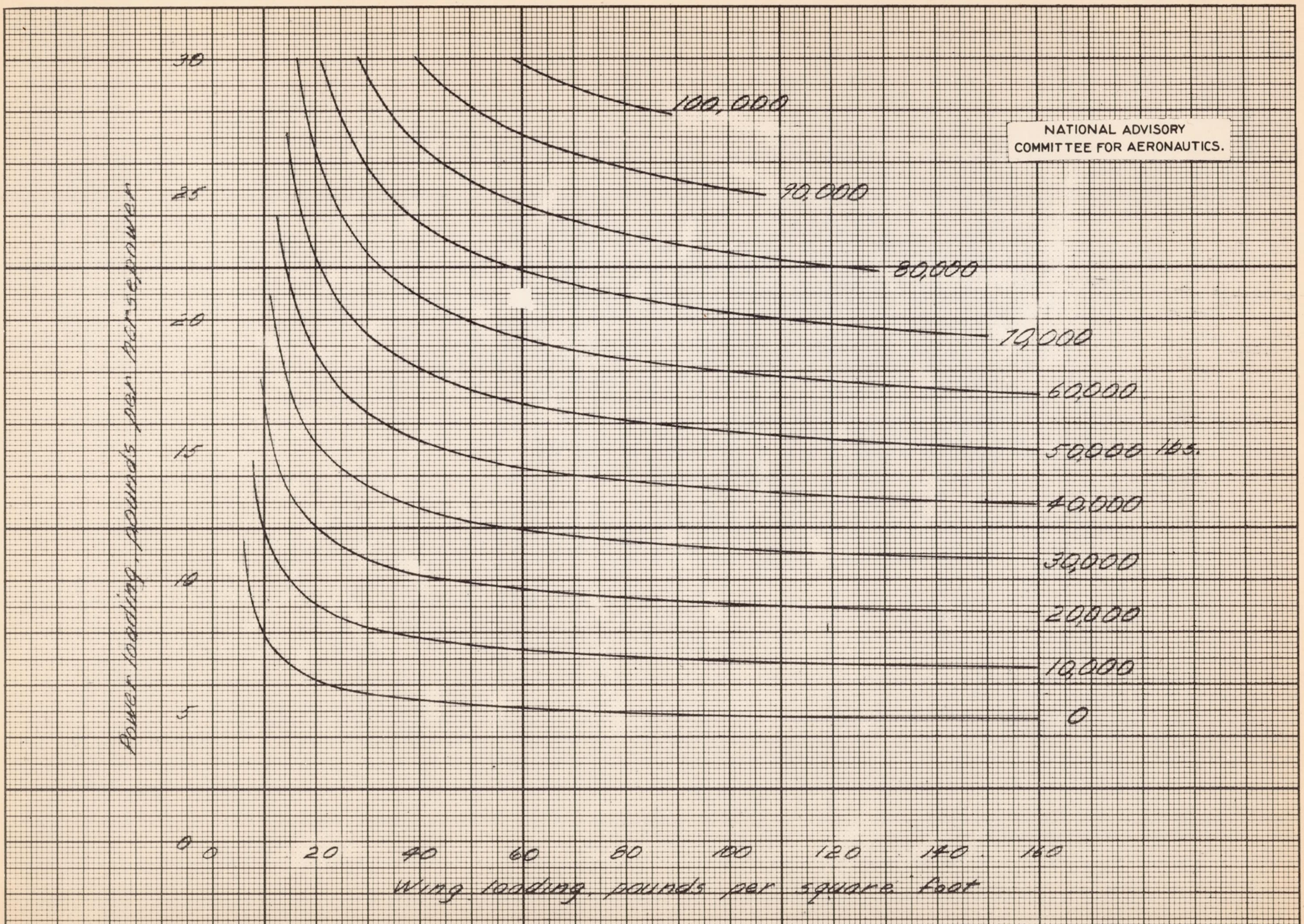

FIG. 21 b DISPOSABLE LOAD WITH 130 % NORMAL STRUCTURAL WEIGHT

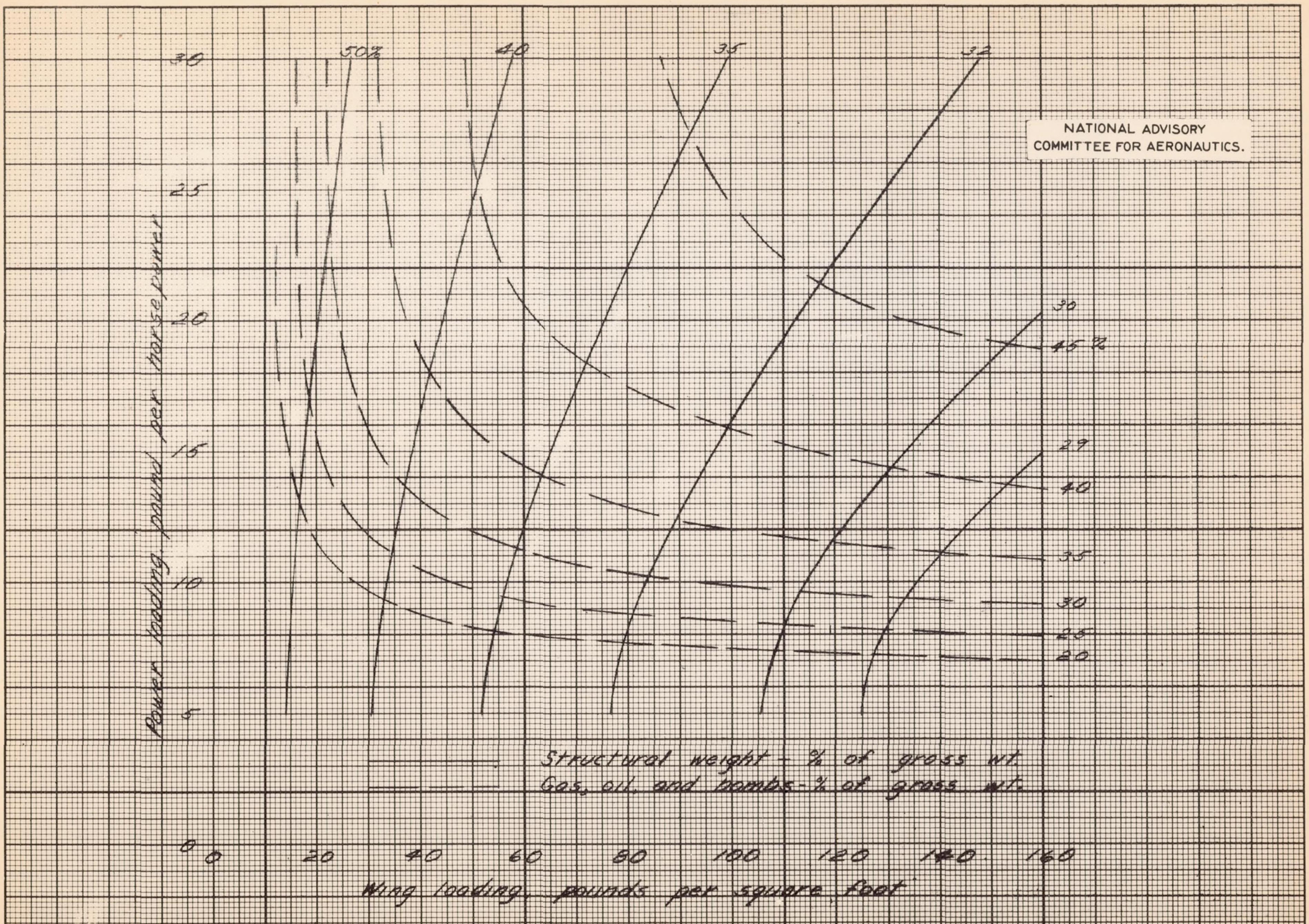

FIG. 21 c WEIGHT CHART: 130 PERCENT OF NORMAL STRUCTURAL WEIGHT.

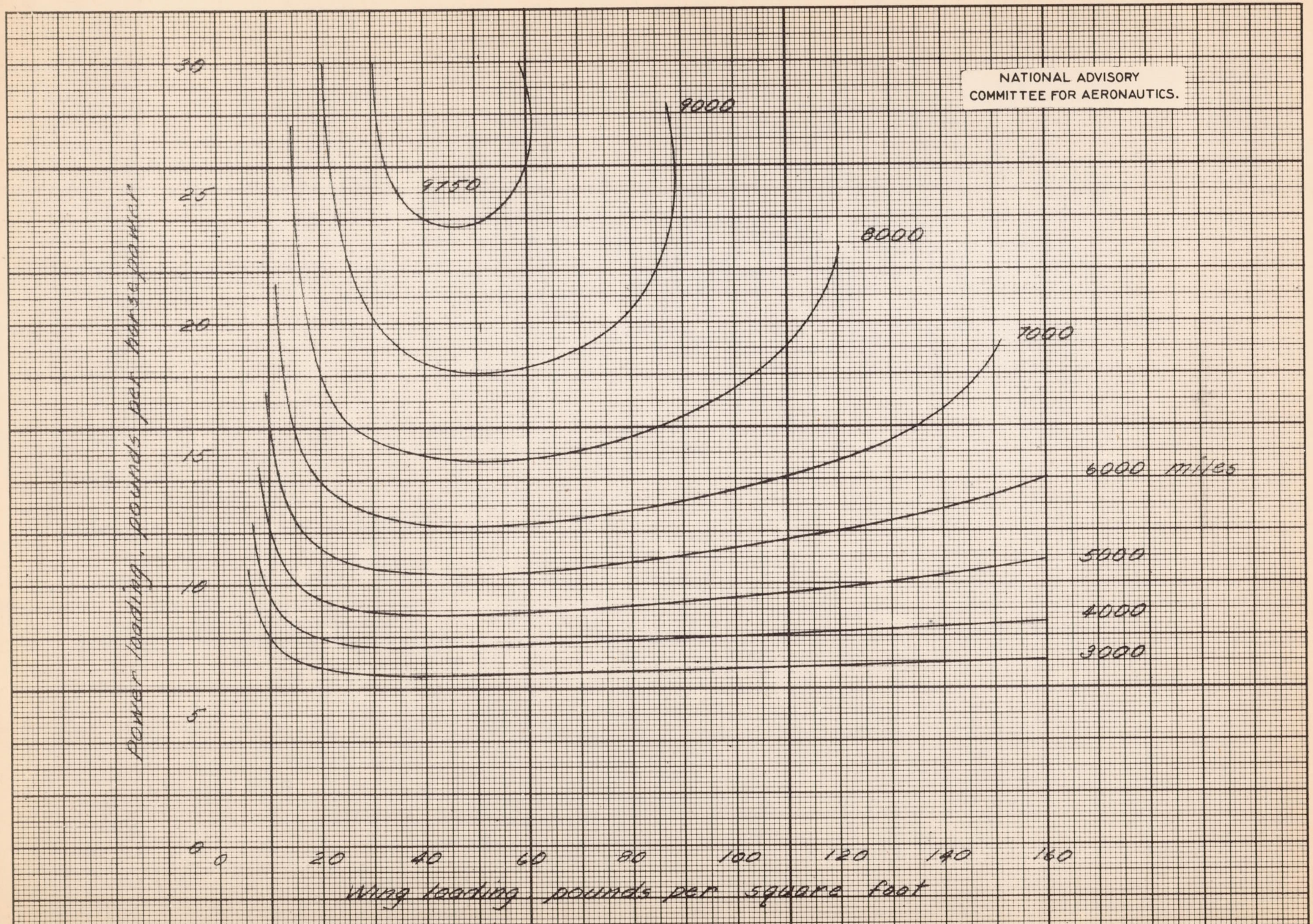

FIG. 22a RANGE CHART USING 70% BASIC FIXED WEIGHT.

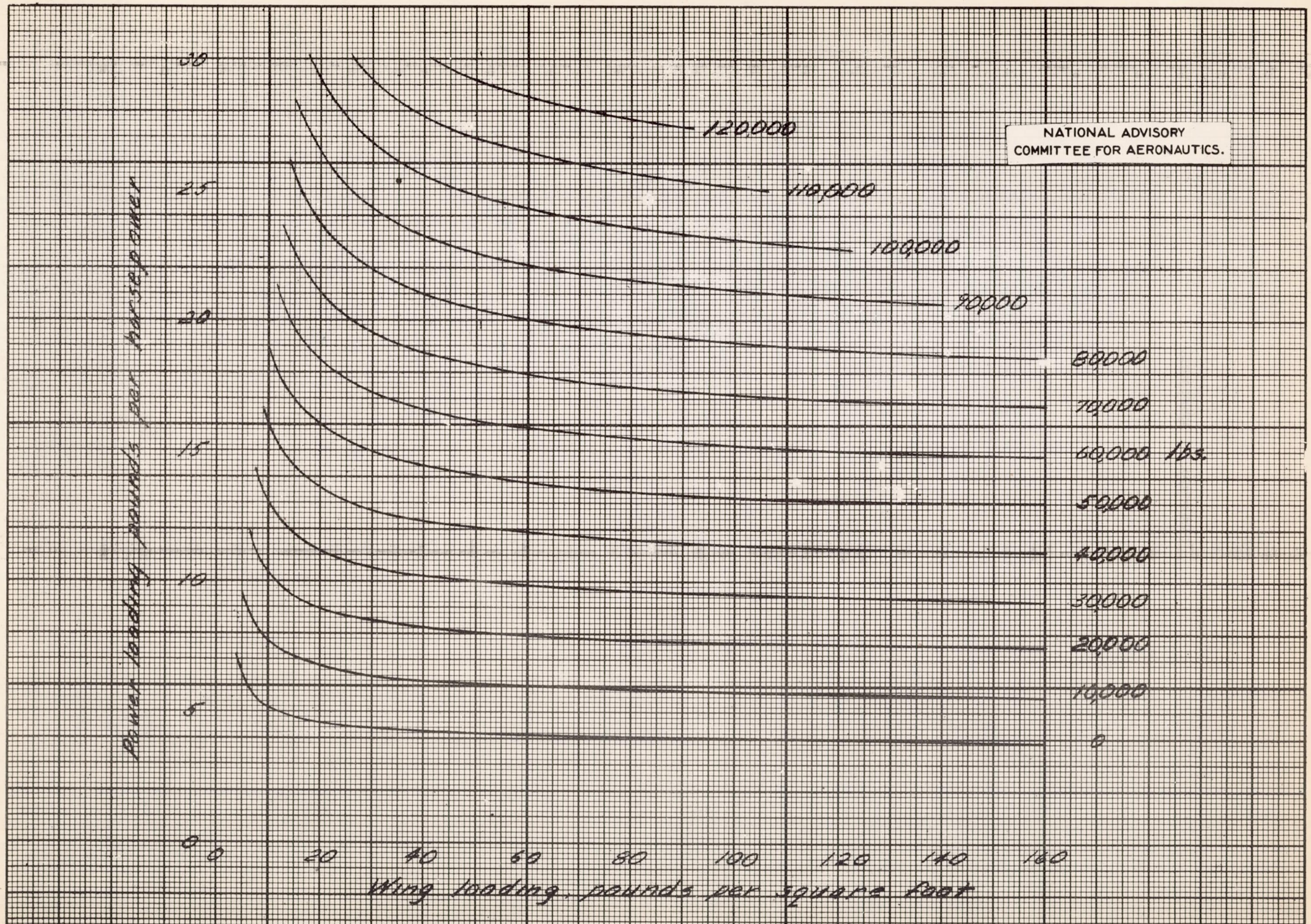

FIG.22b-DISPOSABLE LOAD WITH 70% BASIC FIXED WEIGHT.

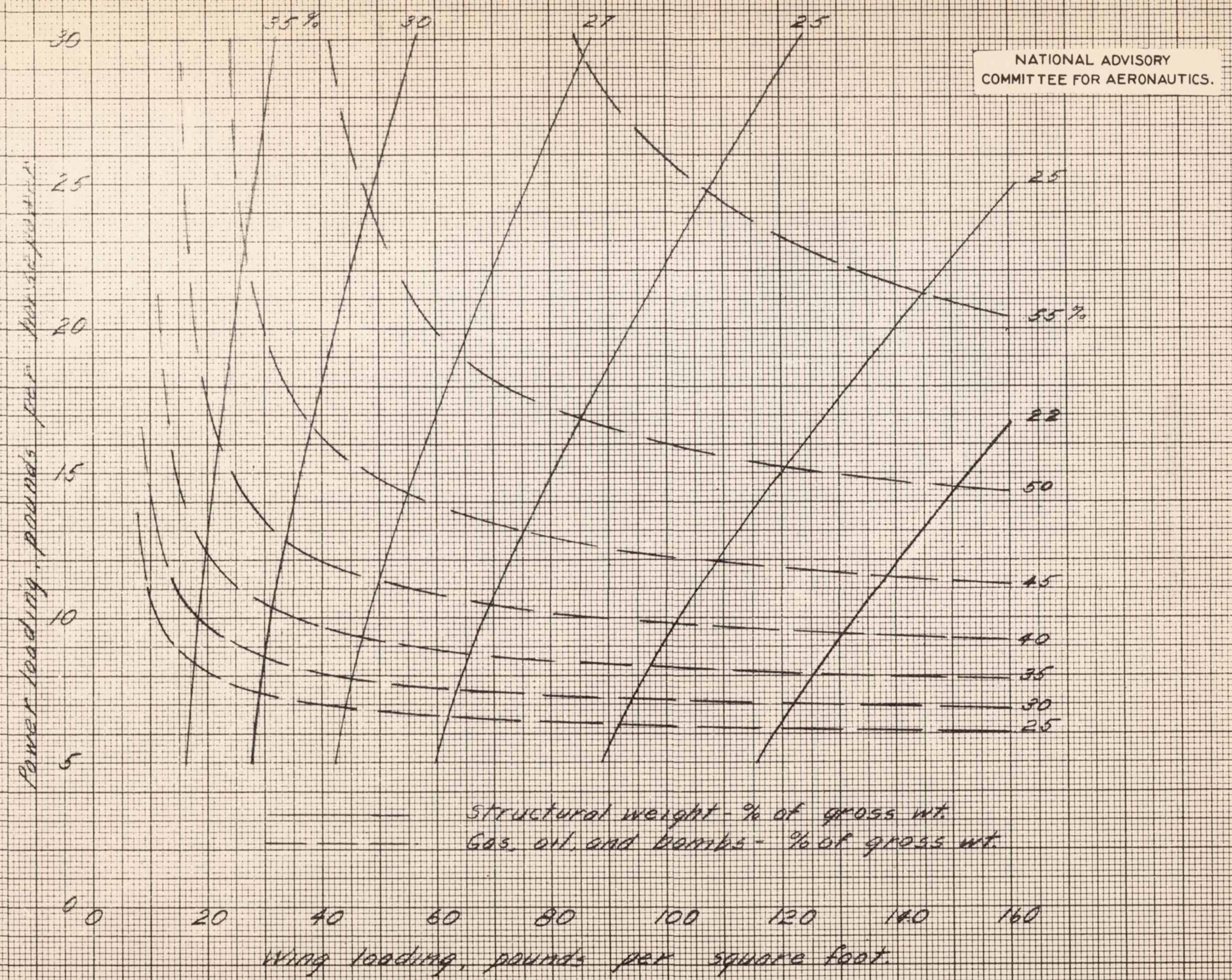

FIG. 22c. WEIGHT CHART: 70 PERCENT OF BASIC FIXED WEIGHT.

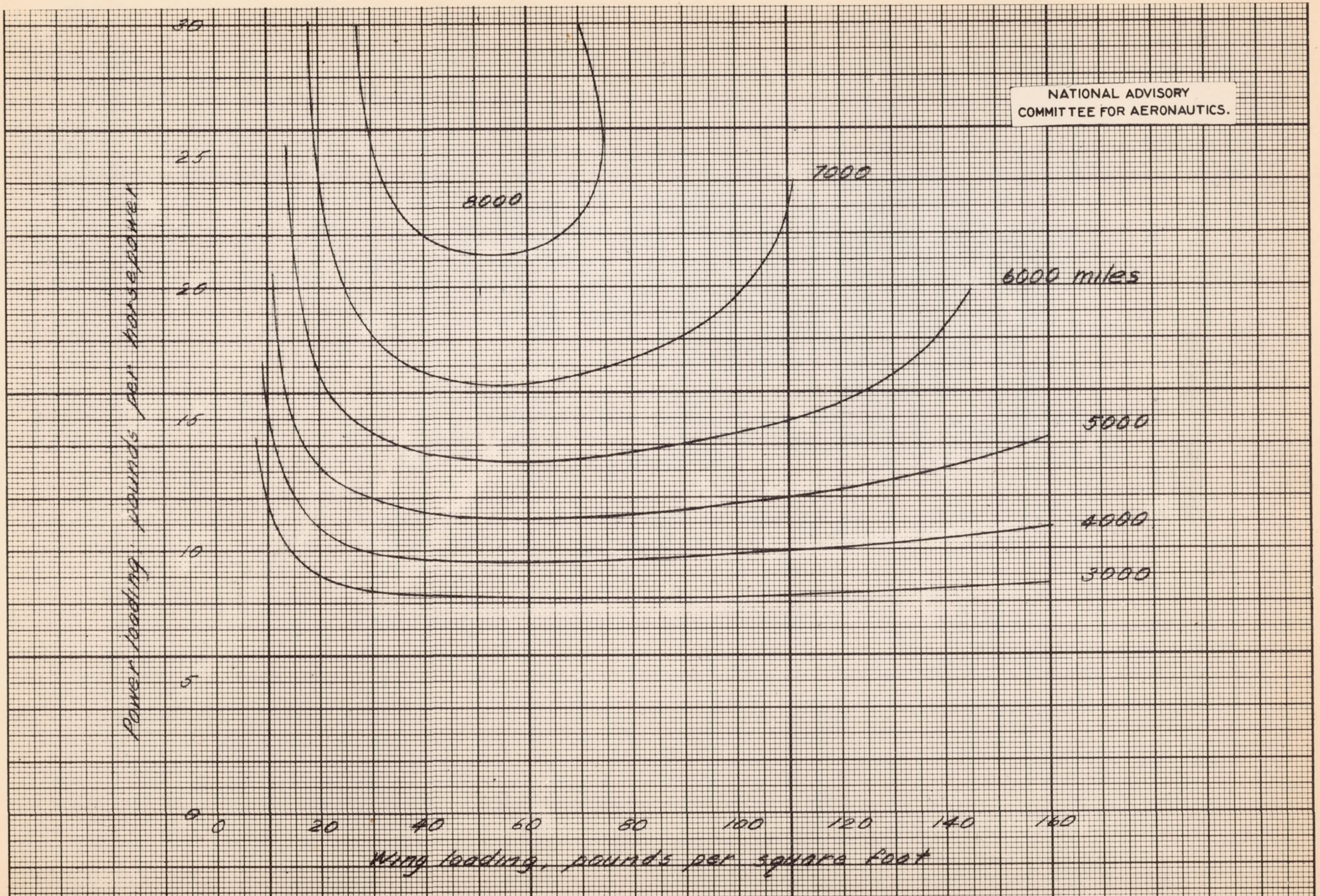

FIG. 23 a- RANGE CHARTS USING 130 % BASIC FIXED WEIGHTS.

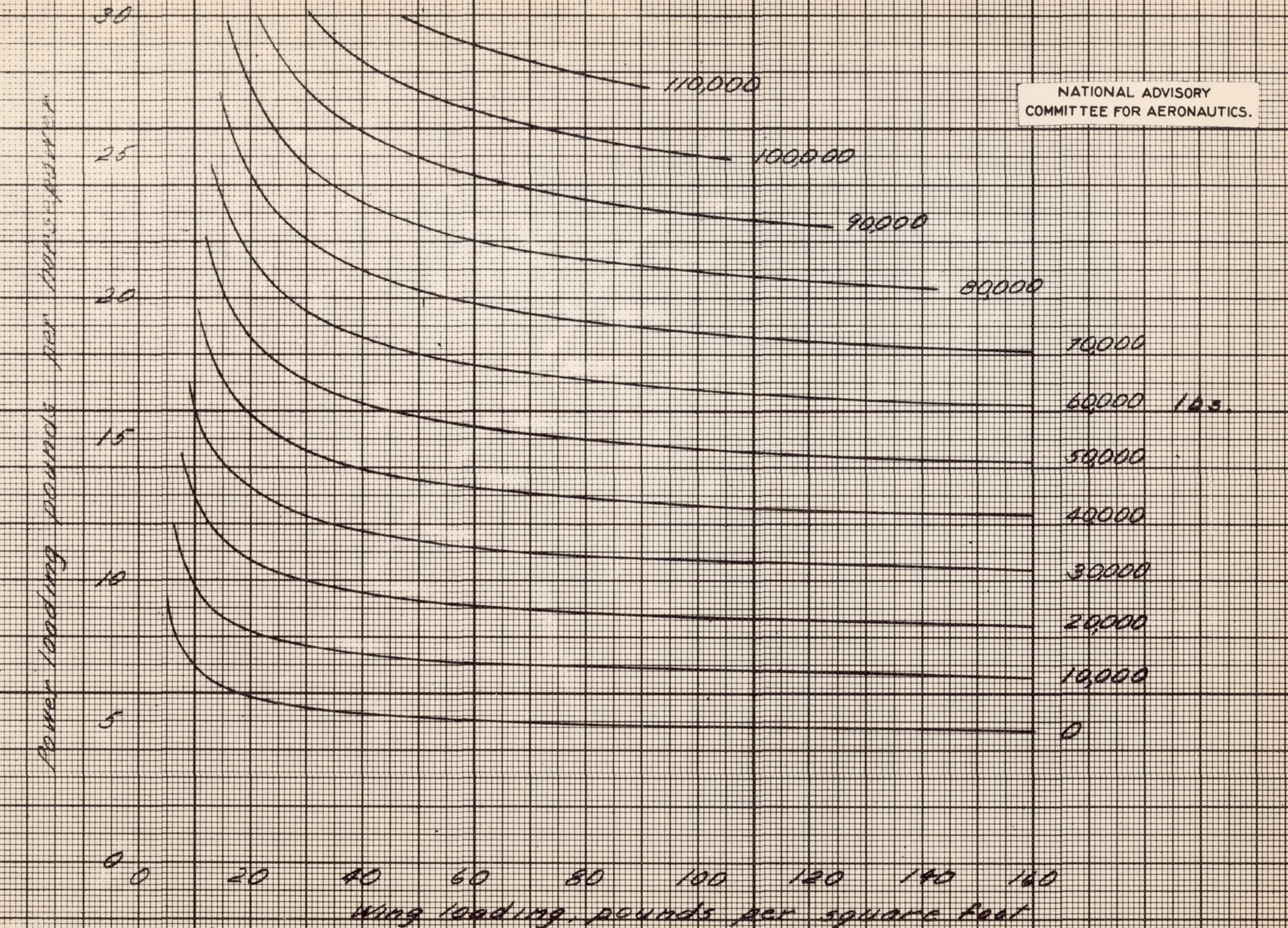

FIG.23b-DISPOSABLE LOAD WITH 130% BASIC FIXED WEIGHT.

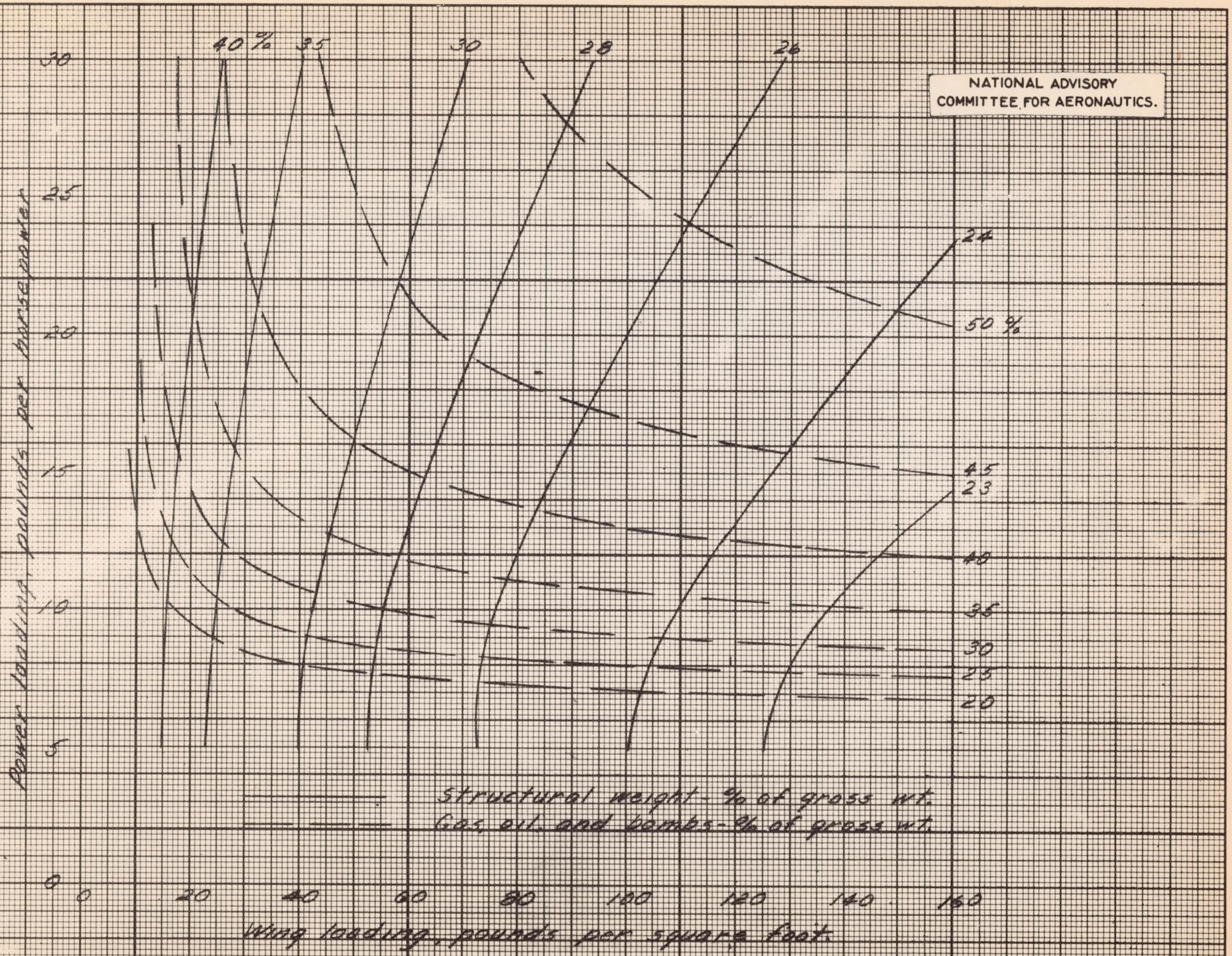

FIG. 23C WEIGHT CHART: 130 PERCENT OF BASIC FIXED WEIGHT

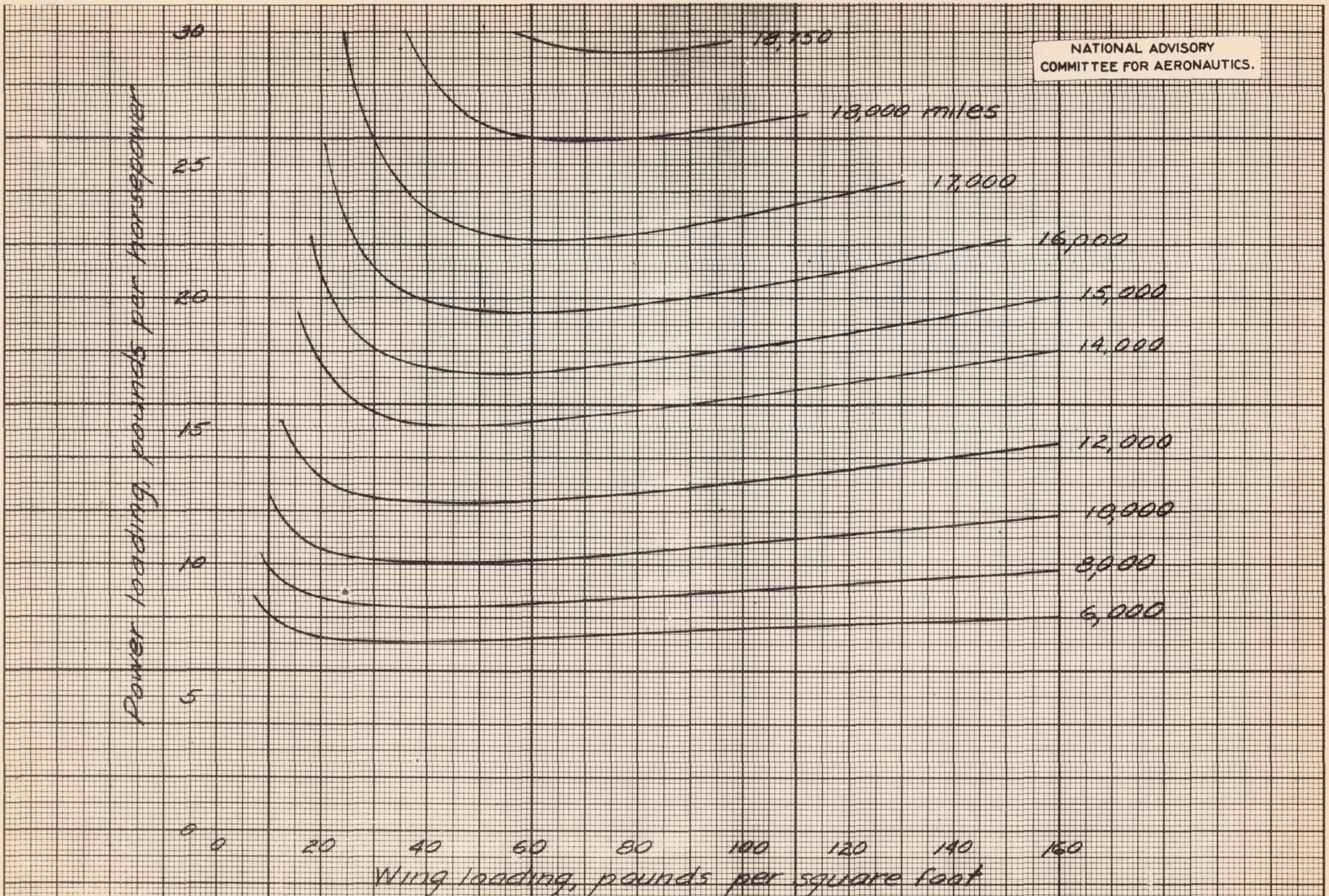

FIG 24 - RANGE CHART USING "IDEAL" S.F.C., "MODEL" DRAG COEFF., 70% NORMAL STRUCTURAL WT.